WORKING PAPERS

1. Dupuy, A., Kennes, J., **Lyng, R. S.**, Job Amenities in the Market for CEOs, ***Job Market Paper***

   We develop a two-sided multidimensional matching model of the market for CEOs that allows for both pecuniary and non-pecuniary (amenity) compensation. The model is estimated by maximum likelihood estimation using matched CEO-firm data from Denmark. We show that CEOs have preferences for building legacy and gaining empowerment. The legacy mechanism explains why there is low mobility in the CEO market even though firms demand general CEO skills. The empowerment mechanism explains why CEOs are willing to sacrifice significant pecuniary income to manage high equity firms. The overall conclusion is that job amenities matter in the market for CEOs.

2. Batsaikhan, M., Gørtz, M., Kennes, J., **Lyng, R. S.,** Monte D., Tumennasan N., Discrimination and Daycare Choice: Evidence from a Randomized Survey, ***Under Review at Journal of Human Resources, IZA Discussion Paper No. 14803***

   We use a randomized survey to study how discrimination affects parenting choices. In our survey, parents with young children choose between two public daycares, which are described by testimonials from other (fictitious) parents. The testifying parents in the first daycare describe a free play institution, which reflects a pro-typical Scandinavian 'permissive parenting' approach to childcare. The testifying parents in the second daycare describe a more structured daycare, which reflects an alternative approach to childcare that is broadly consistent with 'paternalistic parenting'. We randomize the fictitious names of the testifying parents across respondents. We find bias against ethnic minorities among parents who prefer a structured childcare institution but not among parents who prefer free play one. These biases are not reduced when we provide additional information on testifiers' professions. Our findings offer validation for a model of parenting where biases regarding discrimination are likely to come from parents preferring less permissive/more authoritarian methods of parenting.

3. **Lyng, R. S**. & Zhou J., Household Portfolio Choice Before and After House Purchase, *nominated for the Best Paper Awards at the "2018 FMA Annual Meeting in San Diego"*

   Using unique administrative panel data from Denmark, this paper documents the development of households' liquid wealth, equity market participation (the extensive margin), and the conditional risky asset share of liquid wealth (the intensive margin) over a 7-year period around a house purchase. We find that households' equity market participation rate drops during the year of house purchase. Conditional on participation, the risky asset share of liquid wealth follows a V-shape around the house purchase. It decreases and reaches the lowest point 1 year before a house purchase but jumps up immediately after. This finding suggests that of the three channels identified in the literature that affect the risky asset demand after a house purchase, the debt retirement channel and the diversification effect dominate the liquidity concern.

4. **Lyng, R. S**., The Impact of the Financial Crisis on Homeowners' Portfolio Choice

   This paper examines the mediating effect of the recent financial crisis on the relationship between house value fluctuation and households' liquid portfolio choice. To isolate exogenous variation in homeowners' home equity and mortgage debt before and after the crisis, I use a new regional level construction cost index along with other commonly used house price determinants as instruments. Using an administrative register-based panel data for the entire Danish population in the period 2004 – 2012, I find that the effect of housing on households' risky asset holdings is asymmetric before and after the crisis. The elasticity of risky asset shares with respect to mortgage debt and home equity is -0.31 and 0.28 respectively in pre-crisis period. On the other hand, whereas for the post-crisis period, the elasticity of risky asset shares with respect to mortgage debt and home equity is -0.37 and 0.34 respectively. Suppose an average household had spent 10% more on housing, the estimates suggest that they would

hold 6% less in risky shares pre-crisis and 7% less post-crisis. Homeowners rebalance their liquid portfolio to a larger extent in response to their housing value fluctuation after the financial crisis, adding an additional effect that is likely to exacerbate the instability of an already tumultuous financial system.

5. Kennes, J., **Lyng, R. S.** & Zhou J., Household Portfolio Choice at Mortgage Runoffs: A Regression Discontinuity in Time Analysis

   Lack of participation in the stock market remains an ongoing discussion in finance. Brown, Veld & Veld-Merkoulova (2018) find that Perceived Equity Risk Premium (PERP), defined as the difference between the individual's expected stock market return and her personal opportunity cost of capital, can explain limited stock market participation, but were unable to provide causal evidence on that. We examine the causal impact of PERP on portfolio choice by estimating changes in portfolio choice at the time of mortgage runoffs. We merge administrative register-based panel data from Statistics Denmark with individual mortgage transaction data from the Association of Danish Mortgage Banks. Using a Regression Discontinuity in Time (RDiT) framework, we find the probability of equity market participation increases discontinuously at mortgage runoff, and conditional on equity market participation, the share of liquid wealth held in risky assets decreases discontinuously. Our result confirms Becker and Shabani (2010) theoretical prediction, and is consistent with Brown, Veld & Veld-Merkoulova (2018) and the life-cycle model prediction of Davis, Kubler and Willen (2006). PERP is an important determinant for portfolio choice.

WORK IN PROGRESS

1. with Ronald Wolthoff and John Kennes, Matching and Welfare Analysis of the Danish Mortgage Market

   Buying a home is the most important financial decision that most people will make in their life. The primary sources of finance for households when buying a home are banks and mortgage credit institutions (MCIs). The types of mortgage products offered by these institutions deeply affect individuals' lifetime well-being. This project investigates how the structure of, and changes in, the mortgage market affect both individual and overall social welfare.

   While it is a matter of course that households ultimately choose their institutions and mortgage products, it is also important to recognize that the institutions themselves have incentives to choose customers with specific characteristics. These incentives are sometimes influenced by regulatory concerns. For example, the Danish FSA introduced in 2016 restrictions on the number of loans a bank can serve to customers for which the Loan to Income (LTI) ratio exceeds a factor of 4 in the Copenhagen metropolitan area and Aarhus. This is an example of a macroprudential policy which has become a focus point for policy makers since the financial crisis in 2007. To assess the welfare impact of new and potential developments in the mortgage market, it is important to consider both sides of the market and how they interact. In this project, we

   1) determine what drives the terms of trade, i.e. pricing and other details of a mortgage contract, and the assignments between any particular individual and institution, and

   2) determine how individuals and institutions will behave in response to structural and regulatory changes in the mortgage market.

We do this by extending state-of-the-art theoretical and empirical methodologies and applying it to unique data covering the population of Danish individuals and the universe of credit institutions and mortgage transactions. This project will help to improve the quality of the Danish mortgage market by identifying direct and indirect trade-offs associated with policy proposals aimed at managing systemic risks. For example, policy makers would be interested in a counterfactual policy experiment that removes a particular institution (e.g. Bank A goes bankrupt) or a type of mortgage product (e.g. interest-only loans), to determine how the portfolio of loans for the remaining institutions will be impacted, and which customer types will experience the greatest losses/gains in the mortgage market.

Theoretical foundation: We will analyse this pattern of banking relationships and the allocation of gains within these relationships using a two-sided revealed preference framework. Our framework assumes individuals and institutions can compensate each other using transfer payments, which the literature refers to as transferable utility (TU). Moreover, participants on both sides of the market operate competitively and can freely choose trading partners subject to finding agreeable terms of trade. Our theoretical foundation is the "two-side stable matching model with TU" framework which is well known in the market design literature, pioneered by the Nobel Prize winners Alvin Roth and Lloyd Shapley, also known as the Becker model referring to Becker (1973). To estimate this Becker model, we will extend recent developments in econometric methods presented in Fox 2007, 2010, 2018, Akkus et al., 2016, and Fox, Yang & Hsu, 2018.

2. with Arnaud Dupuy, John Kennes and Peter Rohde Skov, Teacher and Principal Labor Markets and School Performance

   Measuring and improving the quality of school leadership and teaching is of fundamental importance in education. This project uses a two-sided multidimensional matching model to provide a full cost-benefit analysis of public policies that impact the assignments of principals/teachers to schools/classrooms. In particular, we will (1) estimate the potential amenities of teaching/managing "easy-to-serve classrooms/schools" for each type of teacher/principal in terms of their wages; (2) estimate how much inequality exists across schools with regard to the quality of teachers and principals; (3) evaluate the impact of counterfactual policy proposals, such as a change in the wage cap of teachers for one group of schools, on the assignments of more effective teachers to disadvantaged schools; (4) obtain new estimates on value-added measures for teachers and principals that take into account the selection of teachers and principals into schools, and (5) compare estimates on the selection and performance of teachers within schools with estimates from other studies. We extend state-of-the-art theoretical and empirical methodologies and apply it to the new and unique matched teacher-to-classroom and principal-to-school data from Denmark. A country that has decentralized school systems and school performance can be measured through national test scores. Our project will develop operational tools for the policymakers to improve the quality and governance of public schools. We aim to provide proof of practice for the general application of our methods to other education systems. Our project is multidisciplinary, involving a combination of education, pedagogy, and developing of quantitative methods. It includes the transfer of knowledge to both academic and public sector, and the training of researcher in new advanced econometric methods. This study contributes to the EU strategy to develop school education systems and strengthen European identity through high-quality education.

1 Excellence

1.1 *Quality and pertinence of the project's research and innovation objectives*

Measuring and improving the quality of school leadership and teaching is of fundamental importance in education. In the past decades, researchers have made considerable advances in creating credible value added measures (VAMs) that evaluate how teachers' cognitive and non-cognitive skills impact student performance (see, for example, Hanushek [1971], Chetty et al. [2014a], Chetty et al. [2014b], Chetty and Hendren [2018], Rothstein [2017], and Chetty et al. [2016]). For example, relevant role models are shown to be effective for teaching math to girls and for creating lasting school engagement with disadvantaged children (Terrier [2020], Carlana [2019], Sansone [2017], and Gørtz et al. [2018]). The impact of effective management is evidenced in Branch et al. [2013], and Anderson and Kimball [2019]. These studies give insights in what characteristics, motivation and training of teachers and principals best match the learning needs of a heterogeneous student population. While they are useful in measuring the **resulting benefits** of assigning different teaching and management resources to different groups of students, they provide no guidance on the **costs** of delivering alternative education services to different types of students.

The **costs** of assigning teachers and principals to different classrooms/schools are of practical concerns. For example, we know that effective teachers (Nye and Hedges [2004], Rivkin et al. [2005], and Araujo et al. [2016]), and principals (Hoffman and Tadelis [2021], and Branch et al. [2013]) can improve student and school performance. But we also know that teachers and principals have preferences for teaching/managing in schools with 'easy to serve students' (Boyd et al. [2003], and Jones and Hartney [2017]). In particular, within the context of a decentralized school system, which is a major element of the European educational systems, evidence indicates that more experienced and qualified teachers tend to choose schools with high achieving students, fewer minority students, students from high-income families, and schools that are safer and experience fewer disciplinary problems (Boyd et al. [2005], Clotfelter et al. [2005], and Sorensen and Holt [2021]). **This means that not only schools choose their principals and teachers, principals and teachers themselves have the incentives to choose schools with specific characteristics.** So **how much do principals and teachers need to be compensated to be assigned to more difficult to serve students? Are these assignments at all feasible given the limited resources and monetary compensations the government has to offer? Other than pecuniary compensation, can teachers and principals be compensated by things other than money, which we call job amenities**[1]**?** In this project, we seek to estimate both costs and benefits in the teacher and principal labor market. Our project will provide a full **cost-benefit analysis** of potential public policies that impact the assignments of teachers and principals to different schools. The objective of our study is to develop ***operational tools*** for the policymakers to improve the ***quality*** and ***governance*** of public schools. For example, we will evaluate how changes in the salary cap for a group of disadvantaged schools will impact teacher quality in these schools. This project is closely related to the EU strategy to develop school education systems and strengthen European identity through high-quality education.

We achieve the objective by extending state-of-the-art theoretical and empirical methodologies and applying it to the new and unique data from Denmark.

Why Denmark? The Danish education system is unique in several ways, but mostly resembles the issues of shared concerns at the EU-level, for example, immigrant students are at higher risks of poor performance, and inequality exists between schools in terms of leadership and teacher quality. The Danish school system is highly decentralized. Most financial and personnel management decisions are taken at the local and school level (OECD [2020a]). Decentralization in education systems is a heavily debated topic in the EU. Evidence suggests that decentralization creates a greater opportunity for developing innovative forms of inclusive education, and improves school governance, Stubbs [2008], Busemeyer [2012]. But on the other hand, researchers also point out that since decentralization increases competition and school autonomy, this system may exacerbate the differences between schools and education outcomes, and in the longer term, social inequality, Herbst and Wojciuk [2017].

[1] For example, the enjoyment of the teaching easy to serve students. "Amenity" and "Pecuniary compensation" are explained in Section 1.2

Therefore, focusing on Denmark can help the EU identify the strengths and challenges a decentralized school system might face, and enrich our knowledge along multiple dimensions of a decentralized school system.

Another reason for focusing on Denmark is because of the administrative register-based panel data available on the education system. We have i) matched teachers/principals to classrooms/schools data; ii) standardized measures of classroom and school performance, such as "national test scores". These test scores can be matched to classrooms within schools (The Danish Ministry of Education [2014]). iii) detailed school characteristics, for example, diversity of students, composition of labor force, location, class size, etc. from the education institution register iv) detailed teacher and principal characteristics, including but not limited to demographic information such as age, gender, education, marital status, number of children, age of each child, from the Danish civil registration system (CPR Registeret); income and financial information, such as wage, perks, tax-free salary, anniversary and severance pay, the value of stock options, remuneration for board work, fees in connection with consulting work, lectures and the like, net wealth, bank debt, from the Danish tax authority (SKAT); real estate information such as the size and tax value of each registered property from the real estate statistics register (Ejendomsstatistik Registeret); and cognitive and non-cognitive skills such as the principals and teachers' test scores from when they were students, their alma mater schools and districts, any pedagogy courses they attended, their major in University, the hours they have taught, each subject they have taught, etc. These data covers 95% of all Danish primary and lower secondary schools, and all of their corresponding students and work force. The high-quality data is essential for our research methodology.

1.2 *Soundness of the proposed methodology*

Overall Methodology: We assume principals and schools (likewise teachers and classrooms) are characterized by a set of attributes only partly observed by the researcher. Principals (teachers) aim to match with the type of schools (classrooms) that can maximize their utility, whereas schools (classrooms) aim to match with the type of principals (teachers) that can maximize their performance. Participants on both sides of the market operate competitively and can freely choose partners subject to finding agreeable terms of employment, which is justified in a highly decentralized market like Denmark. Moreover, we assume that principals and schools (teachers and classrooms) can compensate each other using transfer payments, that are pecuniary compensations, for example salaries and incentive packages, which the literature refers to as transferable utility (TU). Our theoretical foundation is the "two-sided matching model with TU" framework, which is well known in the market design literature, pioneered by the Nobel Prize winners Alvin Roth and Lloyd Shapley.

Researchers have encountered many methodological limitations regarding the quantitative methods available to identify and estimate features of the two-sided matching models. In some markets, the transfer payments are not observed, for example, in the fields of family economics with marriage market, Choo and Siow [2006]. Some empirical studies only allow agents to be differentiated by a single dimension, and therefore either ignore the effect of other attributes on sorting (see, for example, Charles et al. [2013]), or assume all observed characteristics are important in sorting, but have to collapse all attributes into one single index (see, for example, Chiappori et al. [2012]). Some have to restrict that the agents' characteristics are discrete (see, for example, Galichon et al. [2021] and Galichon and Salanié [2010]).

We develop a model for the principal and teacher labor markets by extending state-of-the-art empirical methodologies. Our model is close in spirit to Dupuy and Galichon [2014], Dupuy et al. [2020], and Dupuy and Galichon [2021] and can overcome all the methodological limitations mentioned above. This means that we have a multi-dimensional matching model, where we allow agents on both sides of the market to be differentiated by multiple characteristics. We also assume continuous agent types. In fact, we can accommodate both continuous (for example, age, years of education, test scores) and discrete characteristics (for example, gender, have or don't have certain qualification). We observe transfer payments, which are principals and teachers' pecuniary compensations, i.e. salary, incentive packages and any other fringe benefits. We also allow frictions on transfers through taxation. We also allow for sorting to occur on attributes that are unobserved to the econometrician. **In addition to these advances, we will extend the methodology to account for the partially non-transferable utility (NTU) case**, which is relevant in the teacher and principal labor market due to the fact that their wages are subject to salary caps. To explain this in another way: as long as the salary is below the cap, we observe the transfer payments, therefore the problem lies within matching with TU case; once the salary is above the cap, we no longer observe

the transfer for this portion, therefore the problem becomes matching with NTU.

This project will produce two papers on the market for principals and teachers respectively.

Integration of methods and disciplines to pursue the objectives: Before explaining how the methodology can be applied to our setting, it is important to define pecuniary compensations and amenities. We define amenities as a form of compensation to the workers that cannot be transferred into monetary units by conventional methods of accounting. For example, an amenity can be the enjoyment of teaching in an alma mater school, or managing a top-rated school. This is contrasted by the worker's pecuniary earnings, which will include all sources of compensation for which it is straightforward to calculate a monetary value, such as base wage, perks, for example, a company provided car or a company paid personal secretary, tax-free salary, anniversary and severance pay, remuneration, fees in connection with consulting work, lectures and the like. Importantly, pecuniary compensations are typically taxed as personal income by the tax authorities, whereas amenities are not taxed.[2]

The objective of our empirical methodology is to obtain (i) estimates of the value added of teachers and principals in different classrooms and schools, and (ii) estimates of the amenity value teachers and principals get from different classrooms and schools. Our method is based on a labor market model of how schools select principals and teachers. Our assumptions are: (1) the market is large so that there is a large number of principals (teachers) of any given observable type x and there is a large number of schools (classrooms) of any given type y; (2) principals (teachers) select the type of schools (classrooms) that can maximize their utility, whereas schools (classrooms) select the type of principals (teachers) that can maximize their performance; (3) school and classroom performance are measured by students national test scores, which are public information in Denmark and closely monitored by parents and policymakers; (4) wages offered to teachers and principals are subject to salary caps, which differ by school characteristics.

Our model is very general. We can apply the proof of Dupuy and Galichon [2021] that a maximum likelihood estimator (MLE) exists and that the equilibrium can be solved by the Iterative Proportional Fitting Procedure (IPFP) algorithm. Applying the MLE, we can separately identify school (classroom) performance and principals' (teachers') job amenity. Our model estimates give insights into which amenities offered by schools and classrooms are valued by principals and teachers, as well as which skills of principals and teachers are important in improving school and classroom performance. Crucially, we can quantify job amenities to teachers and principals in terms of monetary values, which might be difficult to achieve outside our analysis. For example, we can quantify how much salary teachers are willing to trade off for teaching in a gentrified neighbourhood to upper middle-class students.

Since our estimates are derived from a structural model, these estimates can be used for counterfactual policy analysis. For example, we can predict the impact of a change in the salary cap for one type of school (or for one type of teacher) on the performance of all schools competing for teachers.

Methodological contribution: We will be the first to apply and extend a set of new developments in econometric analysis Dupuy and Galichon [2014] Dupuy and Galichon [2021] Dupuy et al. [2020] Dupuy et al. [2021] Galichon and Salanié [2021] to the analysis of teacher and principal labor markets. Our study will be the first study that uses these methods to

1. Estimate the potential amenities of teaching/managing "easier to serve" classrooms/schools for each type of teacher/principal in relation to the value of their wages;

2. Estimate how much inequality exists across schools with regard to the quality of teachers and principals;

3. Evaluate the impact of counterfactual policy proposals, such as a change in the wage cap of teachers for one group of schools, on the assignments of more effective teachers to these schools;

[2]Following this definition, fringe benefits, for example, a company provided car, extra insurance, are taxed. So it is part of pecuniary compensation, not amenities.

4. Obtain new estimates on value added measures for teachers and principals that take into account the selection of teachers and principals into schools; and

5. Compare estimates on the selection and performance of teachers within schools with estimates from other studies.

Gender dimension and other diversity aspects: Our research will help the policymakers to understand which types of teacher/principal can add value to the performance of female students, ethnic minority students; ghetto area students; and disadvantaged students. More importantly, we also give policymakers operational tools to quantify the costs of assigning the right teachers and principals to the right classrooms and schools, thereby improving the overall and relative performance of schools.

Open Science practice: We will provide open access to our two working papers. We will disseminate our results throughout the project in local seminars, international conferences. We will also organize a public workshop on education. There are lots of stakeholders in education, we will discuss our results with policymakers, teachers and parents to ensure our research can be applied in real policy experiments and benefit the society to the largest extent possible. More specifically, Ran will interact with the Danish Ministry of Education and visit VIVE (VIVE is an independent government institution under the Ministry of the Interior and Housing, where Ran will spend 6 months at the end of the project period). We will also make our Matlab code available for researchers, to ensure reproducibility of our results, and for them to apply our methods using data from other European countries. We aim to prove the general practice of our method in this project and encourage other researchers to apply our method. Details on our dissemination and exploitation plan are described in Section 2.2.

Research data management and management of other research outputs:
Institutional Background: In the Danish decentralized school system, most financial and personnel management decisions are taken at the local and school level (OECD [2020a]). While the Danish school system is highly decentralized, it is also highly collaborative. In particular, Danish schools and local authorities have more responsibility for decision-making related to personnel and resource management than elsewhere in the OECD, but there is less regarding the organisation of instruction (OECD [2020b]). The collaborative elements of the Danish system are found in its overarching goals and policies, such as bench-marking through national testing and general salary negotiations that set common limits (and allowances on these limits) on teacher and principal salaries. Our method complements these collaborative goals, because it accounts for the highly endogenous selection of teachers and principals, which is a general feature of school systems that delegate key personnel decisions to schools. Important to our study, are a set of institutional initiatives in 2014 that have advanced the collection of new data that i) matches teachers/principals to classroom/schools; and ii) matches national test scores to classrooms within schools The Danish Ministry of Education [2014].

Data: The implementation of our methodology requires the following observations: (1) Information about each teacher/principal that is of relevance to both their performance in classrooms/schools and the sorts of amenities they might value at different schools; (2) Information about each school that is of relevance to the specific and general skills needed of teachers/principals and the amenities given to teachers/principals; (3) Information about the assignment of classrooms/schools to teachers/principals; (4) Performance evaluations of schools and classrooms; (5) Salary limits by relevant school and teacher/principal characteristics.

Data for this project will come from a variety of sources. It will be based on the rich Danish administrative register-based panel data, covering the entire Danish population from 2014 until 2021, administered by Statistics Denmark. This data contains information on schools, employment, education and further education, as well as wages and work experience. Data is linked through the Danish personal identification number (CPR), which are anonymized by Statistics Denmark according to the General Data Protection Regulation (GDPR). One of the co-authors, Peter Rhode Skov, has used the matched teacher-classroom data in Kristensen and Skov [2019]. The researcher Ran Sun Lyng has extensive experience in managing and using data from Statistics Denmark. All five of her working papers and the 2 papers she is currently working on are using data from Statistics Denmark.

The project will further use new data provided by an initiative between Statistics Denmark, The Danish Ministry of Education and other research institutions to improve the education system. These data will enable us to link stu-

dents with teachers, schools and principals. We can use key identifiers to link teachers and principals to classrooms and schools. It covers more than 95 percent of all public schools, students and teachers and is made available by The Department for IT and Learning services (Styrelsen for IT og Læring (STIL)), from 2014 onwards. Our data covers the competencies of the teachers, the hours they have taught, each subject they have taught, and the teacher's cognitive and non-cognitive skill measures. These data also contain similar information on principals. We can link this information to other administrative registers, where we are able to have a rich set of information on teachers and principals, such as wages and their grades from upper secondary education (Gymnasium), their grades from their teacher college and working experience. For students, we are able to link them to their schools, classrooms, to their family background, and we also know the students' grades at the end of compulsory schooling.

For a subset of schools, teachers and principals, we will use data from the 2014 Danish School Reform. These data, collected through surveys, contain information on the teachers' work happiness, their self-efficacy, teaching styles and their evaluation of the schools' principals. The data on the teachers covers 15,000 teachers, across 200 schools, from 2014 to 2018. Data on principals covers around 78 percent of all principals in Danish public schools from 2014 to 2018, meaning that there are about 937 schools in all years. These data contain information on the principals' management, recruitment of teachers and work with the teachers, i.e. how they motivate their teachers and supervise their teaching. These data are available through the Danish Data Archives.

1.3 *Quality of the supervision, training and of the two-way transfer of knowledge between the researcher and the host*

Ran will be supervised by Prof. dr. Arnaud Dupuy. Arnaud has extensive experience in supervising young researchers. He was the main advisor of 5 PhD students at two institutions (Maastricht University and University of Luxembourg) and co-supervisor of another 10 PhD students. Between 2013 and 2016 he was the head of the labour market department at LISER comprising 25 (junior and senior) researchers. Since 2017, he is the co-Principal Investigator of a large-scale Doctoral Training Unit funding by the Fond national pour la Recherché (FNR) in Luxembourg. This DTU offers 13 PhD positions and as many main supervisors, and provides doctoral students with training on migration, labour and inequality issues. Arnaud has also successfully led large scale (>600,000 euro) research projects financed by the FNR, involving 4 postdoctoral researchers.

In the last decade, Arnaud's research has contributed to developing estimation strategies for matching models when agents' attributes are possibly continuous, multivariate and some are unobserved to the analyst. He has used tools from discrete choice models, convex analysis, linear programming and optimal transport. Arnaud has applied these methods to various datasets: administrative records, households surveys, labor force surveys, data on performance and pay in sports. In this research area, Arnaud has published 13 articles in top-tier academic journals such as the Journal of Political Economy, the International Economic Review, Quantitative Economics, the Journal of Applied Econometrics, etc. in collaboration with 9 different authors. His main collaboration on this topic is with Prof. dr. Alfred Galichon (NYU, Sciences Po Paris) and Simon Weber (York University) and in the last three years, Arnaud has been working intensively in collaboration with two groups of researchers on related research topic: the first group is composed of Prof. dr. Laurens Cherchye (KU Leuven), Prof. dr. Bram de Rock (ULB) and Prof. dr. Frederic Vermeulen (KU Leuven), the second is the collaboration with Ran and Prof. dr. John Kennes (Aarhus University).

Arnaud teaches two courses on matching models at the PhD level within the doctoral school in economics and finance at the University of Luxembourg. Ran will participate actively and contribute to the further development of these courses. It is anticipated that Ran will also provide guest lectures on the work that she has done matching methods and present her research in the economics department seminar series. Postdoctoral researchers at the University of Luxembourg benefit from a generous budget for mobility, allowing them to attend conferences and workshops but also to visit their international collaborators. Ran will also be asked to take part in the co-organization of a workshop on matching models applied to labor and marriage markets together with Arnaud and the group of researchers at KU Leuven mentioned above.

Last but not least, the department of economics at the University of Luxembourg works on many projects in

close collaboration with LISER, a research center in Luxembourg, specialized in socio-economic topics. Ran will benefit from this collaboration by interacting with post-doctoral researchers at LISER working on labor issues, but also working in close connection with the ministry of education on issues related to the teacher and principals labor market. It is anticipated that these interactions would lead to new projects applying similar methods as those developed in the current project, but applied to Luxembourgish data.

1.4 *Quality and appropriateness of the researcher's professional experience, competences and skills*

Ran Sun Lyng is a recent PhD graduate from Aarhus University. She is currently doing a postdoc at the University of Toronto. Her postdoctoral research is focused on empirical applications of matching theory. She is applying related matching model and estimation technique, i.e. Fox [2007, 2010] and Fox [2018], in retail banking market. Her PhD thesis studied household behavior in the Danish financial markets, where she has gained considerable experience in the use of Danish register data, programming, and the estimation of structural models of the type described in this proposal.

Ran has expertise in econometric methods, broad experience in both academic and non-academic research (doing policy analyses for the Canadian national bank in the retail mortgage market), as well as good teaching evaluation. She manages three different projects on Statistics Denmark's servers. She has demonstrated independent thinking and leadership qualities in research through managing big data sets, collecting valuable data from various sources, and effectively communicating with government agencies. Ran has shown herself an extremely competent and hardworking collaborator. She is building a strong international network in both academic and non-academic research.

She has the skills and appropriate professional experience and competences to complete the proposed project. In terms of research methodology, she has a working paper that uses a similar matching model in the market for CEOs, co-authored with Arnaud Dupuy and John Kennes. Similar method (but with methodological advances) will be applied to a new market, i.e. principals to schools and teachers to classrooms, in this project. In terms of the research topic, she has experience in studying school choice. Ran has a reject and resubmit paper at Journal of Human Resources that studies the relationship between parenting styles and attitudes toward ethnic minorities in a daycare setting, using survey data and register data from Statistics Denmark. In that project, she worked closely with the city of Copenhagen and learned a lot about the districts and schools in the Danish public education system. That paper looks at how parental choices affect students outcomes, whereas in this proposal, we look at how school/teacher affect student outcomes.

2 Impact

2.1 *Credibility of the measures to enhance the career perspectives and employability of the researcher and contribution to his/her skills development*

Research skill development proceeds quite naturally by doing research. In Ran's area of research, the relevant theoretical and empirical methods include stochastic dynamic programming, duration models, matching models, network models, strategic models, dynamic equilibrium models, econometrics/machine learning/big data methods, the analysis of register data, and other data types. While all of these skills are important, her general skill as a researcher is to develop her skills in finding important economic problems that can be solved by appropriate choices of methods and data. The set of problems Ran will study at Luxembourg will serve her quite well in both developing specific skills needed to apply advanced scientific methods, and general skills to identify important economic problems and solutions.

Her general research question is to find ways to understand the problem of creating valuable economic and social relationships and to determine how these relationships give value not only to the side of the market being served but also to the side of the market doing the service. There is a range of potential applications that can be addressed using similar matching models Ran learns to use in this proposed project, for example: (1) Homeowners serve markets by making improvements to their homes that are valued by prospective home buyers but also serve themselves by choosing a home that brings them personal satisfaction; (2) Psychiatrists serve patients by providing psychiatric services but can also serve themselves when they decide which patient to accept; (3) CEOs serve

the market by managing valuable firms, but also serve themselves by choosing to work in firms that give them satisfaction such as an opportunity to build a legacy and to be empowered; (4) Teachers serve schools by helping students do well on important exams, but can also serve themselves by choosing classrooms that they find "easier to serve" and give them enjoyment on teaching.

Ran's fundamental research contributions in the analysis of key service markets will undoubtedly lead to high-quality publications. Since these problems are also of policy importance, her research will lead to consultation with policymakers, which is also valued by her future academic employers. In the service of her research, Ran is acquiring exciting new data from a variety of sources. This will not only serve her research in the present project, but will also be valued by academic departments wishing to create research teams that use such data. Finally, since the methods Ran is developing and using are valuable and can be taught, academic departments will find demand for her skills in the classroom.

By focusing Ran's research at Luxembourg on the impact of teacher and principal labor markets on school and classroom performance, she will establish early publications in leading economic journals. Furthermore, this research will lay out a methodological foundation where she can apply her research methods in other important applications. This will serve to advance her academic career so that she can be a leading researcher in Europe on topics of importance to the EU.

Some specific aims of the research plan that will further Ran's career are as follows:

1. Publications in top general interest journals. Additionally, publications in important field journals as Ran expands the scope of her investigations to new data sets in different education contexts;

2. Conference and workshop participation in both European and North-American high-profile conferences and workshops. Also, seminar presentations in academic departments. It is important that other researchers see that she has thought deeply on the topics she is researching on. A key springboard for Ran's outreach in North America is her current postdoc at the University of Toronto, where she is working on applications of matching models to financial markets, i.e. individual and banks matching; CEO and firm matching.

3. Developing teaching related to her study. For example, John Kennes at AU has asked Ran and Arnaud to teach a graduate course on the methods and applications in a DGPE (Danish Graduate Program Economics) course. Ran is a very strong teacher with excellent teaching rankings at Aarhus University.

4. Policy consultation. We will host workshops both in Luxembourg and in Denmark where Ran can explain the results of her research to policymakers and advisors. Key partner here is VIVE, who works in the fields of society, health, governance, education, children and young people, employment, integration, elderly care, economics and public sector management. Ran will spend 6 months at VIVE as an integral part of this project to directly interact with policymakers and experts of the Danish education system.

5. Developing and applying method to other key service market. For example, we have pinpointed the health-care sector as another service provision activity where service results can be observed (for example, patients' cognitive health) and where detailed data can be acquired that matches healthcare providers to patients.

2.2 *Suitability and quality of the measures to maximise expected outcomes and impacts, as set out in the dissemination and exploitation plan, including communication activities*

The focus of our research is on developing new empirical tools and data to evaluate how the teacher and principal labor markets impact school and classroom performance. Given the importance of the tools and the topic, we will seek peer review and acceptance in top economics journals. We plan to have two publications, which correspond to our analysis of the teacher and principal labor markets. The papers will be presented at international workshops and conferences and published in the working paper series of IZA, before being sent to top journals.

The study of how education systems impact learning is highly inter-disciplinary. The science of education addresses questions of student motivation, appropriate learning material, and teacher cognitive and non-cognitive competencies. Accurate measures of these aspects of education are important inputs in our empirical methods. Moreover, since the feasibility of any proposed learning path must depend on getting teacher and management compliance, our research provides important quantitative analysis on the costs of implementing teaching methods. Therefore, there are synergies for intra-disciplinary education research for both the inputs and outputs of our research methods. To facilitate these synergies, we will organize at least one inter-disciplinary workshop to create

awareness of our methods and results. We will actively interact with LISER (Audrey Bousselin in particular) on developing strategies to extend our analysis beyond the Danish data to the Luxembourg data. Audrey is also involved with the ministry of Family in Luxembourg and has therefore access to data of similar quality as those for Denmark. We will organize a workshop in Luxembourg on the topic towards the end of the project.

Our analysis is of importance of municipalities and neighborhoods that must compete for effective teachers. The results of our research will determine if the competition for teachers and principals is a level playing field, or whether some schools are better able to compete for more effective teachers and why. Since fair access to quality education is a concern of all parents, we plan public outreach regarding our study. We will produce at least one white paper that summarizes our empirical findings. This position paper will be published as a working paper at VIVE both in Danish and in English. This paper will give a popularized discussion of our methods, which will be accessible for journalists, policymakers, and the public.

Our analysis is also of importance to the teaching profession, because we document which classrooms and schools are less desired by teachers and principals. This evidence will create opportunities to better define the duties and compensation of teachers and principals, so that quality education is available to all students. Therefore, both the union of teachers and the union of principals will be consulted about our research results. This is important because the creation of our data is a joint initiative of the Danish Ministry of Education and the Danish Union of Teachers.

To maximise expected outcomes and impacts, we will make the computer programs and documentation needed to run our estimation methods freely available. We will also provide consultation to other researchers on how to apply these methods with other school systems outside the context of our immediate study.

2.3 *The magnitude and importance of the project's contribution to the expected scientific, societal and economic impacts*

Ran's research uses advanced empirical methods and exciting new data to isolate two important motivations behind service provision - job performance and job satisfaction - see examples in 2.1. This is important for economic policy because (1) Welfare analysis must account for the benefits of trade for all parties in the relationship. (2) Evidence based policy interventions in markets must identify both the determinants of supply (job satisfaction) and the determinants of demand (job performance). (3) The determinants of who provides and uses public services - such as teachers and students in schools - is central to questions of fairness and equality. (4) If job satisfaction is an important driver of service, policies that impact the usage of wages as an allocative mechanism (such as salary caps in the case of the public sector or progressive taxes as in the case of the private sector) will invariably create a stronger weight for job satisfaction as an allocative mechanism.

Since our objectives are of central concern for policymakers in all OECD countries, and we are offering substantive methods to achieve these objectives, we anticipate that separate studies of principals and teachers will lead to two high-quality publications in top general interest economic journals. Furthermore, we expect that our results will provide proof of practice for the general application of our methods to other education systems. Therefore, our long-term plan is to share our skills and collaborate with other researchers in the analysis of school systems, both inside and outside the context of the current study.

3 Quality and Efficiency of the Implementation

3.1 *Quality and effectiveness of the work plan, assessment of risks and appropriateness of the effort assigned to work packages*

Most of the key research milestones will be delivered over four equal intervals of a 2-year plan, while the last 6 months will be used for outreach. In work package (WP) 1 (6 months), we will secure data and clean it. At this stage, we will use descriptive analysis to characterize heterogeneity and correlations between schools/classrooms and principals/teachers. In WP2 (6 months), we will develop and estimate our model, making technological advancements on the programming methods we applied in our CEO project Dupuy et al. [2021]. We will test various model specifications, estimate our model and do robustness checks. In WP3, we will write up two working papers, where we explain our methods, give context, and provide economic explanations of our model estimates. We will discuss our results in local seminars at Luxembourg, Aarhus and VIVE. Counterfactual policy experiments will be carried out. By the end of WP3, we expect to have at least one working paper. And by the end of WP5,

we plan to make two working papers available in IZA working paper series. WP4 contains the preparation of a public workshop on education. We will secure keynote speakers, organize PhD courses in connection with the workshop, and send out invitations for paper submissions. In WP5, we disseminate our results and respond to critical suggestions. The public workshop will take place at the end of WP5. We also expect to present this work in international conferences in this stage. Dissemination will happen at the end of each WP to ensure we are on track. Ran will have weekly meetings with Arnaud, with substantial sessions at key stages such as WP2 and WP3 and at the end of each WP. The last 6 months at VIVE is for outreach. There are many stakeholders in education. Our research will speak to the concerns of parents as well as teachers and principals. We will reach out to policymakers, teacher and principal unions during this stage and discuss our findings and the application of our methods. Finally, by the end of the 2.5 years, we plan to have two papers submitted to top journals.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WP1: Collect Data and produce descriptive statistics	X	X	X	X	X	X																		
WP2: Model specification and model estimation							X	X	X	X	X	X												
WP3: Explain our results, run counterfactual policy experiments, and write up two working papers													X	X	X	X	X	X					X	X
WP4: Prepare for a workshop on education																			X	X	X			
WP5: Dissemination, present our papers in international conferences and organize a public workshop on education						X						X						X	X	X	X	X	X	X

Risk Management: The assurance of the work plan is given by 1) Arnaud and Ran have already partnered on a different topic, i.e. the market for CEOs, using similar methods and data structures. 2) Peter Skov from VIVE, who will also participate on this project, has experience using the matched teacher-to-classroom data in his work. So there is no risk of not having the data, or the data not living up to the quality we expected. 3) Ran has experience gathering and merging data from various research institutions. 4) Ran has extensive experience in data manipulation and data management on Statistics Denmark's server. The work plan shown above has considered the possible delay due to Covid-19 related issues.

3.2 *Quality and capacity of the host institutions and participating organisations, including hosting arrangements*

The successful applicant will be hired by the host institution under an employment contract for the duration of the project. Upon contract start, the supervisor and department administrative staff will welcome the new recruit on site and invite them to an introduction session by the University HR department. The new team member will work in an office at the department premises and receive standard IT equipment.

University of Luxembourg has very experienced support services to support the implementation of 3rd party funded projects. The central Research support department, and research facilitators working at research department level advise on and support contract and project management, as well as reporting. HR services and EURAXESS office are involved in work contract and benefits matters and can help with relocation.

VIVE - The Danish Centre for Social Science Research also confirm that they will participate and contribute to the research, innovation and training activities as planned in this project. In particular, VIVE will be involved in providing access to data and assist with data preparations and analyses.

References

Shannon W. Anderson and Amanda Kimball. Evidence for the feedback role of performance measurement systems. *Management Science*, 65(9):4385–4406, 2019.

M. Caridad Araujo, Pedro Carneiro, Yyannú Cruz-Aguayo, and Norbert Schady. Teacher Quality and Learning Outcomes in Kindergarten *. *The Quarterly Journal of Economics*, 131(3):1415–1453, 03 2016.

Donald Boyd, Hamilton Lankford, and Susanna Loeb. The Draw of Home: How Teachers' Preferences for Proximity Disadvantage Urban Schools. NBER Working Papers 9953, National Bureau of Economic Research, Inc, September 2003.

Donald Boyd, Hamilton Lankford, Susanna Loeb, and James Wyckoff. Explaining the Short Careers of High-Achieving Teachers in Schools with Low-Performing Students. *American Economic Review*, 95(2):166–171, May 2005.

Gregory F. Branch, Eric A. Hanushek, and Steven G. Rivkin. School leaders matter: Measuring the impact of effective principals. *Education Next*, 13(1):62–69, winter 2013.

Marius R Busemeyer. Two decades of decentralization in education governance: Lessons learned and future outlook for local stakeholders. In *Presentation delivered at OECD conference,'Effective local governance in education*, 2012.

Michela Carlana. Implicit Stereotypes: Evidence from Teachers' Gender Bias*. *The Quarterly Journal of Economics*, 134 (3):1163–1224, 03 2019.

Kerwin Kofi Charles, Erik Hurst, and Alexandra Killewald. Marital sorting and parental wealth. *Demography*, 50(1):51–70, 2013.

Raj Chetty and Nathaniel Hendren. The Impacts of Neighborhoods on Intergenerational Mobility II: County-Level Estimates*. *The Quarterly Journal of Economics*, 133(3):1163–1228, 02 2018.

Raj Chetty, John N. Friedman, and Jonah E. Rockoff. Measuring the impacts of teachers ii: Teacher value-added and student outcomes in adulthood. *American Economic Review*, 104(9):2633–79, September 2014a.

Raj Chetty, John N. Friedman, and Jonah E. Rockoff. Measuring the impacts of teachers i: Evaluating bias in teacher value-added estimates. *American Economic Review*, 104(9):2593–2632, September 2014b.

Raj Chetty, John N. Friedman, and Jonah Rockoff. Using lagged outcomes to evaluate bias in value-added models. *American Economic Review*, 106(5):393–99, May 2016.

Pierre-André Chiappori, Sonia Oreffice, and Climent Quintana-Domeque. Fatter attraction: anthropometric and socioeconomic matching on the marriage market. *Journal of Political Economy*, 120(4):659–695, 2012.

Eugene Choo and Aloysius Siow. Who marries whom and why. *Journal of Political Economy*, 114(1):175–201, 2006.

Charles T. Clotfelter, Helen F. Ladd, and Jacob Vigdor. Who teaches whom? race and the distribution of novice teachers. *Economics of Education Review*, 24(4):377–392, 2005.

Arnaud Dupuy and Alfred Galichon. Personality traits and the marriage market. *Journal of Political Economy*, 122(6): 1271–1319, 2014.

Arnaud Dupuy and Alfred Galichon. A note on the estimation of job amenities and labor productivity. *Quantitative Economics*, forthcoming, 2021.

Arnaud Dupuy, Alfred Galichon, Sonia Jaffe, and Scott Duke Kominers. Taxation in matching markets. *International Economic Review*, 61(4):1591–1634, 2020.

Arnaud Dupuy, John Kennes, and Ran Sun Lyng. The market for CEOs: building legacy and feeling empowered matter. *working paper*, 2021.

Jeremy T Fox. Semiparametric estimation of multinomial discrete-choice models using a subset of choices. *The RAND Journal of Economics*, 38(4):1002–1019, 2007.

Jeremy T Fox. Identification in matching games. *Quantitative Economics*, 1(2):203–254, 2010.

Jeremy T Fox. Estimating matching games with transfers. *Quantitative Economics*, 9(1):1–38, 2018.

Alfred Galichon and Bernard Salanié. Matching with trade-offs: Revealed preferences over competing characteristics. *CEPR Discussion Paper No. DP7858*, 2010.

Alfred Galichon and Bernard Salanié. Cupid's Invisible Hand: Social Surplus and Identification in Matching Models. *The Review of Economic Studies*, forthcoming, 2021.

Alfred Galichon, Bernard Salani'e, et al. Cupid's invisible hand: Social surplus and identification in matching models. Technical report, techreport, 2021.