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Challenges of Using Mobile Positioning Data in Geographical Studies

Rein Ahas
University of Tartu
e-mail: rein.ahas@ut.ee

Discipline: Economics and Game Theory

The aim of the presentation is to introduce the advantages and disadvantages of using mobile telephone based datasets in studying social geography and spatial networks. The advantage of mobile phone databases is the possibility to connect digitally telephone users with their spatial mobility, phone use and communication network data at the ID level. This enables to study the communicative connections between the individuals and their spatial mobility of entire countries. It is, however, difficult to obtain such composite ID level network data from census, traditional statistical sources and most of nationwide surveys. In the presentation, I will be introducing the case studies and applications implemented in Estonia with the help of mobile data and the accompanying methodological and legal challenges. I will also be introducing the initiative of mobile-based data in statistical system, which is being developed in cooperation with Eurostat.

Addressing Urban Challenges in a Complex World with Network Approaches

Céline Rozenblat
University of Lausanne
e-mail: celine.rozenblat@unil.ch

Discipline: Human and Economic Geography

In the context of knowledge and information societies, new tendencies in the long/medium term evolution of urban systems, together with new data and methods, require that existing theoretical assumptions and conceptualizations would be challenged as global urban hierarchies are reconfigured. The connection between urban systems at different scales becomes more and more relevant for understanding urban systems and their transformations. But the inter-urban perspective is not sufficient to encompass these dynamics. Local networks are involved in macro-geographical level, mutual reinforcing of their overall influence to other cities. Therefore the reticular process operating within cities is directly related to city type of centrality at intercity level, needing to formalize further the “local buzz, global pipelines” at the world and local scales. The evolution of power distributions inside and between cities reshapes the world organization of central/peripheral cities and the complexity of the global urban system. In the complexity of this multi-level system, how regionalization of the world is reshaping in a multipolar urban world? How some cities develop relay roles between international and national systems? These questions are addressed with methodologies derived from a combination of evolutive economic geography and complex systems sciences bringing new forms of intelligibility on these urban dynamics.

The Wiring of a Country and its Economic Consequences

M. Coscia

Harvard University, Center for International Development
e-mail: michele_coscia@hks.harvard.edu

Discipline: Human and Economic Geography

Keywords: Human Mobility, Social Networks

A country is a complex organism composed by a myriad of interacting parts: its inhabitants. Each inhabitant coordinates only to a small extent with other inhabitants. The emerging behavior of a country is therefore a decentralized and complex phenomenon. In my talk I am focusing on one specific country: Colombia. The talk is divided in two parts. In the first part, I am going to show how it is possible to reconstruct the social network of a country by using anonymized phone call metadata. In the second part, I will provide one example of what this social network means for the development of the country.

When a person operates her phone there are two pieces metadata that can be used to infer the internal structure of a country. First, we can analyze who is she calling. Second, we can know which are the locations visited by the same phone, by recording to which towers it connected to perform its calls. Using the anonymized information about who calls whom, we built a network whose nodes are Colombian municipalities and connections are established if a significant number of people in one municipality call people in another. Exploiting movement information, we can build another network, again at the municipality level, recording not calls, but physical phone movements. When we compare these structures, we discover that telecommunication follows the same dynamics of physical movements. The distance discount is weaker, but it is still unlikely to have long-distance telecommunication links. This suggest that telecommunications did not nullify distance, as they were designed to.

The geographical constraint in which the social network is embedded has economic repercussions. We focus on the problem of economic convergence. Poorer areas are expected to grow faster and catch up with richer areas. However, many scholars observed the opposite phenomenon, economic divergence, where the gap between rich and poor widens. We too fail to find unconditional economic convergence in Colombia. Poor municipalities in rich states in Colombia diverge: their average wage growth is penalized. But if we assign a municipality to a social cluster, i.e. the set of municipalities they talk to, we do find evidence for economic convergence. If you diverge from the municipalities in the same political unit as you, you converge to the development level of the municipalities having strong social links with you.

Using Structure and Content to Reveal the Evolution of Narratives in Social Media

Mariano Beguerisse-Díaz
Mathematical Institute University of Oxford
e-mail: beguerisse@maths.ox.ac.uk

Discipline: Human and Economic Geography

Keywords: Networks, Social Media, Text analysis

The wealth of data available from a variety of sources presents attractive opportunities in academia and beyond. Analysing large datasets and extracting useful information from them is not a trivial task. Often, collections of data have several layers of structure, are complex and noisy. Data from social media and other sources can be processed in many ways; recently we have studied a dataset of relationships among Twitter users who were prominent during the 2011 riots in England. These data consist of the names and descriptions of the users and their mutual relationships (i.e., who follows whom). Although the data did not include the actual messages that passed through these links during the riots, we are able to study the structure of the relationships to reveal information about the users, their interests, hierarchies and roles. Analyses of the network structures created by relationships or interactions between the data-generating agents, however, cannot answer questions such as: what topics do users of social media talk about, and how do these topics and their user participation change in time? To find answers we must go beyond the meta-data and look at the content produced by the users. To this end, we have developed a method to study large, longitudinal collections of textual data that allows us to understand the evolution of discourse and group narratives. Our method uses topic timelines, a concept we have recently introduced. Topic timelines are networks whose nodes are content-units (such as topics) that appear in a given time interval; the edges may depend on the shared authors between the nodes, topical similarity, etc. Handling data in this way creates tractable networks that, for example, not only reveal what topics

appear when, but also help to understand the relationship among the different topics in terms of agent participation or similarity. These new networks can be explored using standard tools from network science. For example, by extracting their communities we can track the origin, evolution, and decline of collective narratives; we can identify which seemingly disparate topics are related through their common users, obtain the user turnover of topics, or know when a topic becomes exhausted for some groups of users but not for others.

These techniques provide a way to make large and complex sets of longitudinal textual data tractable and amenable to analysis with the rich palette of tools from network science, offering a new point of view from which collective discourse can be studied. We showcase our method on collections of Twitter status updates which include conversations about obesity diabetes and the UK's National Health Service. This methodology is applicable not only to social media but to any collection of longitudinal data generated by large numbers of agents.

Cut-Generating Functions for Integer Variables

Sercan Yıldız

Carnegie Mellon University, Tepper School of Business

e-mail: syildiz@andrew.cmu.edu

G erard Cornu ejols

Carnegie Mellon University, Tepper School of Business

e-mail: gc0v@andrew.cmu.edu

Discipline: Operations Research

For an integer linear program, Gomory’s corner relaxation is obtained by ignoring the nonnegativity of the basic variables in a tableau formulation. Their classical result characterizes minimal cut-generating functions in terms of subadditivity, symmetry, and periodicity. In this talk, we consider the general case, where we do not relax the nonnegativity of the basic variables. We show that the Gomory-Johnson theorem still holds if we replace ”periodicity” by the notion of ”nondecreasing function with respect to nonnegative integral vectors”. We also prove a 2-Slope Theorem for extreme cut-generating functions in our setting, in the spirit of the 2-Slope Theorem of Gomory and Johnson.

The Lifting Problem in Cut-Generating Functions

Amitabh Basu

Johns Hopkins University, Dept. of Applied Mathematics and Statistics

e-mail: basu.amitabh@jhu.edu

Discipline: Operations Research

Cut-generating functions are a means to have “a priori” formulas for generating cutting planes for general mixed-integer optimization problems. Given $n \in \mathbb{N}$ and a closed subset $S \subseteq \mathbb{R}^n$ such that $0 \notin S$, a *cut-generating pair* (ψ, π) for S is a pair of functions $\psi, \pi : \mathbb{R}^n \rightarrow \mathbb{R}$ such that

$$\sum_{i=1}^k \psi(r_i) s_i + \sum_{j=1}^{\ell} \pi(p_j) y_j \geq 1 \quad (1)$$

is a valid inequality (also called a *cut*) for the set

$$X_S(R, P) := \left\{ (s, y) \in \mathbb{R}_+^k \times \mathbb{Z}_+^{\ell} : Rs + Py \in S \right\}, \quad (2)$$

for every choice of $k, \ell \in \mathbb{Z}_+$ and for all matrices $R \in \mathbb{R}^{n \times k}$ and $P \in \mathbb{R}^{n \times \ell}$, where the r_i 's and p_j 's are columns of R, P respectively.

Closed form formulas for cut-generating pairs. Given $S \subseteq \mathbb{R}^n$, define $W_S := \mathbb{Z}^n \cap \text{lin}(\text{conv}(S))$. A convex set B is called S -free if $\text{int}(B) \cap S = \emptyset$. A *maximal* S -free convex set is an S -free convex set that is inclusion wise maximal. For many structured S , a maximal S -free convex set B containing the origin in its interior is a polyhedron given by $B = \{r \in \mathbb{R}^n : a_i \cdot r \leq 1 \ i \in I\}$. The following pair of functions associated with B :

$$\psi_B(r) = \max_{i \in I} a_i \cdot r, \quad \pi_B(r) = \inf_{w \in W_S} \psi(r + w) \quad (3)$$

form a valid cut-generating pair. Moreover, the pair is “partially” minimal: for every cut-generating pair $(\psi, \pi) \leq (\psi_B, \pi_B)$, we must have $\psi = \psi_B$.

The main question of this talk is the following:

QUESTION: Let S be a closed subset of $\mathbb{R}^n \setminus \{0\}$. Given a maximal S -free convex set B , decide if (ψ_B, π_B) is minimal, i.e., $(\psi, \pi) \leq (\psi_B, \pi_B)$, implies $\psi = \psi_B$ and $\pi = \pi_B$ for any valid ψ, π .

This approach to cut-generating pairs was pioneered by Dey and Wolsey in [1, 2]. We survey several recent breakthroughs in this approach and fascinating connections with other areas of mathematics such as geometry of numbers and algebraic topology.

References

- [1] Santanu S. Dey and Laurence A. Wolsey. Constrained infinite group relaxations of mips. *SIAM Journal on Optimization*, 20(6):2890–2912, 2010.
- [2] Santanu S. Dey and Laurence A. Wolsey. Two row mixed-integer cuts via lifting. *Mathematical Programming*, 124:143–174, 2010.

Intersection Cuts and S -free Sets for Polynomial Programming

Daniel Bienstock, Chen Chen, and Gonzalo Muñoz
 Columbia University, Industrial Engineering & Operations Research
 e-mail: `chen.chen@columbia.edu`

Discipline: Operations Research

Keywords: Polynomial Optimization, Cutting Planes, Convex Optimization

AMS Classification: 90C26

The intersection cut is a valid inequality developed for integer linear programming. It has an elegant geometric construction and it has since been shown that many families of valid inequalities for integer programming can be interpreted as intersection cuts. The intersection cut has recently been extended to mixed-integer conic programming. In this paper we study the intersection cut in a general context. Given a closed set S and a simplicial cone relaxation $P \supset S$ with apex $x \notin S$, we would like to separate x from S . Let C be a convex set that is S -free (i.e. $\text{int}(C) \cap S = \emptyset$) such that x is in its interior. Then the intersection cut can be viewed as the halfspace V such that $V \cap P = \text{conv}(P \setminus C)$, and $x \notin V$. Larger sets C are necessary to derive deeper intersection cuts, and in integer programming this has led to the study of *maximal lattice-free-sets*.

In the S -free context we derive an intersection cut for an arbitrary closed point set provided a violation distance oracle; call it a *violation ball cut*. We apply this and other intersection cuts to a lifted representation of polynomial programming:

$$\begin{aligned} \min \langle A_0 X \rangle \\ \text{s.t. } \langle A_i X \rangle, \quad i = 1, \dots, m \\ X = xx^T \end{aligned}$$

$\langle \cdot \rangle$ denotes the inner product. The equivalence to polynomial programming is omitted here for brevity; it is the standard technique to form moment relaxations that are representable with semidefinite programming. Dropping the outer product constraint yields a linear programming relaxation in the space of a vector representation of X . S -free is contextualized here to be (real, symmetric) *outer-product-free*, i.e. free in the interior from the set $\{xx^T : x \in \mathbb{R}^n\}$.

We rely on matrix theory to study outer-product-free sets, and operate in the vectorized space to formulate and solve relaxations. For instance, the violation oracle for the violation ball cut is provided by a result in matrix approximation theory. Another result is that the convex cut commonly used to outer-approximate semidefinite programming, $c^T X c \geq 0$ for some $c \in \mathbb{R}^n$, may be interpreted as an intersection cut generated from a maximal outer-product-free set. Furthermore, we can characterize all maximal outer-product-free sets in \mathbb{R}^2 as generating either convex cuts, or *minor cuts*, which are derived from the rotated second-order cone.

Facet Separation with One Linear Program

Michele Conforti

Dipartimento di Matematica, Università di Padova

`conforti@math.unipd.it`

Laurence Wolsey

CORE, Université catholique de Louvain

`laurence.wolsey@uclouvain.be`

Discipline: *Operations Research*

Given polyhedron P and a point x^* , the separation problem for polyhedra asks to certify that $x^* \in P$ and if not, to determine an inequality that is satisfied by P and violated by x^* . This problem is repeatedly solved in cutting plane methods for Integer Programming and the quality of the violated inequality is an essential feature in the performance of such methods.

In the paper we address the problem of finding efficiently an inequality that is violated by x^* and either defines an improper face or a facet of P . We provide some evidence that our method works on structured and unstructured problems.

Models for Piecewise Linear Unsplittable Multicommodity Flow Problems

B. Fortz

Université Libre de Bruxelles, Département d'Informatique
e-mail: bernard.fortz@ulb.ac.be

L. Gouveia

Faculdade de Ciências da Universidade de Lisboa,
Departamento de Estatística e Investigação Operacional e-mail: legouveia@fc.ul.pt

M. Joyce-Moniz

Université Libre de Bruxelles, Département d'Informatique
e-mail: martim.moniz@ulb.ac.be

Discipline: Operations Research

Keywords: Network Design, Unsplittable, Single Path, Piecewise Linear

We discuss unsplittable multicommodity flow problems with piecewise linear cost functions. We focus on the case where these functions are convex - the PUMF problem. However, we also consider the situation when the cost functions are non-convex.

Let $G = (V, A)$ be a directed graph, with a set of nodes V , and a set of arcs A . Consider as well the set of commodities K , each $k \in K$ with a given origin o_k , destination d_k , and demand ρ_k . Each arc $a \in A$ has an associated cost function $g_a(l_a)$ of the load flowing through the arc l_a . This cost function is continuous, convex and piecewise linear, with the segments being represented by the finite set $S_a = \{1, 2, \dots, |S_a|\}$. Each segment $s \in S_a$ has a lower and upper bound on the flow, represented by the breakpoints b_a^{s-1} and b_a^s . If finite, the breakpoint of the last segment of each arc $a \in A$, $b_a^{|S_a|}$, can be interpreted as the capacity of the arc. However, the case where $b_a^{|S_a|} = \infty$ also holds. A segment is also characterized by a slope c_a^s and an intercept f_a^s . Since in the PUMF problem, the cost functions are convex, these values must be such that $c_a^1 \geq 0$, $c_a^s > c_a^{s-1}$ and $f_a^s \leq 0$, $f_a^s < f_a^{s-1}$. Moreover, as we consider the cost function to be continuous, we assume that $b_a^s c_a^s + f_a^s = b_a^s c_a^{s+1} + f_a^{s+1}$. We also assume that for every arc $a \in A$,

$g_a(0) = 0$, and consequently, $f_a^1 = 0$. The PUMF problem is to find a single path for each commodity, such that the sum of the costs associated to the load of the arcs is minimized.

We show that this problem is \mathcal{NP} -hard for the general case, but polynomially solvable when there is only one commodity. We propose a strengthened mixed-integer programming formulation for the problem. This formulation gives a complete description of the associated polyhedron for the single commodity case. We present a wide array of computational experiments, that reveal that this formulation produces very tight linear programming bounds for the multicommodity case.

Evaluating the Quality of Image Graphs for Complex Networks

Stefan Wiesberg

Universität Heidelberg, Institut für Informatik

e-mail: stefan.wiesberg@informatik.uni-heidelberg.de

Gerhard Reinelt

Universität Heidelberg, Institut für Informatik

e-mail: gerhard.reinelt@informatik.uni-heidelberg.de

Discipline: Operations Research

Keywords: Network Analysis, Blockmodeling, Mixed-Integer Nonlinear Optimization

In network analysis, an established way to obtain structural information about a graph is to partition the vertices into so-called regular equivalence classes. In such a partitioning, for any two equivalence classes C and D , either every or no vertex in C has at least one arc to the vertices in D . The relationship between the classes can hence be visualized by a graph, the so-called image graph: Its vertices correspond to the equivalence classes and an arc from vertex C to D indicates that every vertex in C has at least one arc (in G) to the vertices in D . An image graph can thus be seen as a simplification of the original graph G . Image graphs are of interest in the cultural studies, for example in sociology, economics, and consumer research. For real-world networks, image graphs are however usually too large to allow for insightful interpretations. A practically relevant, yet NP-hard problem in this context is the following one: Given a graph $G = (V, A)$ and an image graph R , find a modified graph $G' = (V, A')$ with image graph R , such that the symmetric difference between A and A' is minimized. The value of this minimum difference represents the extent to which R is a suitable image graph description for G .

We express this image graph evaluation problem as a combinatorial optimization problem. To solve it exactly, we formulate it as a nonlinear integer program, which turns out to be a generalization of well-known prob-

lems such as the Quadratic Assignment, Linear Ordering, and the Traveling Salesman Problem. An exact solver is presented which uses new linearization techniques for polynomial constraints and exploits the relations to the problem's well-known special cases. It is able to evaluate image graphs up to 50,000 times faster than a comparable approach from the literature. As this enables us to exactly evaluate networks with more than 100 vertices, we analyze image graphs for the world trading network provided by the United Nations and present new structural results.

Popular Acceptance of Morally Arbitrary Luck and Widespread Support for Classical Benefit-Based Taxation

Matthew Weinzierl
Harvard Business School
e-mail: mweinzierl@hbs.edu

Discipline: Economics and Game Theory

U.S. survey respondents' views on distributive justice are shown to differ in two specific, related ways from what is conventionally assumed in modern optimal tax theory. A large share, and in some cases a large majority, of respondents resist full equalization of economic outcomes determined entirely by luck. A similar share prefer a justification of tax progressivity that relies on a benefit-based logic rather than diminishing marginal social welfare of income, the conventional logic. Moreover, these two views are linked: respondents who more strongly resist redistribution are more likely to prefer the benefit-based principle. Together, these results raise the possibility that the American public views the allocations of taxes and pre-tax outcomes as morally relevant, a judgment that is inconsistent with conventional consequentialist objectives.

A Critical Appraisal of Optimal Income Tax Methodology

Robin Boadway

Queen's University, Department of Economics

e-mail: boadwayr@econ.queensu.ca

Discipline: Economics and Game Theory

Keywords: optimal income tax, equal sacrifice, equality of opportunity, rents

JEL Classification: D6, H2

Social welfare maximization is the dominant approach for analyzing optimal income taxation and its policy implications. The original Mirrlees model has been extended to a multitude of settings, including allowing for multiple commodities, multiple characteristics, multiple periods, uncertainty, intergenerational transfers, and additional policy instruments. It has been used to inform policy recommendations, for example, in the UK Mirrlees Review, and has formed the basis for calibration models of real-world policy choices. Despite its normative appeal and academic popularity, the Mirrleesian optimal income tax paradigm incorporates some non-innocuous assumptions that are crucial for its prescriptive results. These include basing social orderings on consequentialism, relying solely on individual revealed preferences, ignoring preference differences among households, counting all sources of utility including interdependent utility, allowing varying degrees of measurability and comparability of utility, and eschewing deontological approaches. In addition, the Mirrleesian approach ignores sources of rents or windfalls that are important drivers of inequality in the real world. We discuss the consequences of relaxing these assumptions, including alternative approaches found in some important contributions in the literature. Different methodological approaches lead to substantial differences in policy prescriptions. Some of these approaches recall the classical ability-to-pay basis for taxation with its emphasis on

equality of resources as opposed to equality of utilities as an objective of policy.

Voting over Selfishly Optimal Nonlinear Income: Tax Schedules with a Minimum-Utility Constraint

John A. Weymark

Vanderbilt University, Department of Economics

e-mail: john.weymark@vanderbilt.edu

Craig Brett

Mount Allison University, Department of Economics

Discipline: Economics and Game Theory

Keywords: Mirrlees tax problem; nonlinear income taxation; political economy of taxation; redistributive taxation; voting over tax schedules

JEL Classification: D72, D82, H21

Pairwise majority voting over alternative nonlinear income tax schedules is considered when there is a continuum of individuals who differ in their labor productivities, which is private information, but share the same quasilinear-in-consumption preferences for labor and consumption. Voting is restricted to those schedules that are selfishly optimal for some individual. The analysis extends that of Brett and Weymark (*Games and Economic Behavior*, forthcoming) by adding a minimum-utility constraint to their incentive-compatibility and government budget constraints. It also extends the analysis of Röell (unpublished manuscript, 2012) and Bohn and Stuart (unpublished manuscript, 2013) by providing a complete characterization of the selfishly optimal tax schedules. It is shown that individuals have single-peaked preferences over the set of selfishly optimal tax schedules, and so the schedule proposed by the median skill type is a Condorcet winner.

The Political Choice of Social Long Term Care Transfers When Family Gives Time and Money

Philippe De Donder
Toulouse School of Economics
e-mail: philippe.dedonder@tse-fr.eu
Marie-Louise Leroux
Université du Québec à Montréal
e-mail: leroux.marie-louise@uqam.ca

Discipline: Economics and Game Theory

Keywords: Majority Voting, local Condorcet winner, crowding out, intrinsic preference for informal help, tax reform.

JEL Classification: H55, I13, D91.

We develop a model where families consist of one parent and one child, with children differing in income and all agents having the same probability of becoming dependent when old. Young and old individuals vote over the size of a social long term care transfer program, which children complement with help in time or money to their dependent parent. Dependent parents have an intrinsic preference for help in time by family members. We first show that low (resp., high) income children provide help in time (resp. in money), whose amount is decreasing (resp. increasing) with the child's income. The middle income class may give no family help at all, and its elderly members would be the main beneficiaries of the introduction of social LTC transfers. We then provide several reasons for the stylized fact that there are little social LTC transfers in most countries. First, social transfers are dominated by help in time by the family when the intrinsic preference of dependent parents for the latter is large enough. Second, when the probability of becoming dependent is lower than one third, the children of autonomous parents are numerous enough to oppose democratically the introduction of social LTC transfers. Third, even when none of the first two conditions is satisfied, the majority voting equilibrium may entail no social transfers, especially if the probability of becoming dependent when

old is not far above one third. This equilibrium may be local (meaning that it would be defeated by the introduction of a sufficiently large social program). This local majority equilibrium may be empirically relevant whenever new programs have to be introduced at a low scale before being eventually ramped up.

Poverty Reduction, Responsibility and Optimal Income Tax

L. Henry de Frahan
University of Chicago, Economics Department
e-mail: lancelot@uchicago.edu

F. Maniquet
Université catholique de Louvain, CORE

Discipline: Economics and Game Theory

Keywords: Optimal Income Tax, Poverty, Responsibility

We derive the optimal income tax under the combined objective of reducing poverty, holding individuals responsible for their preferences over leisure-consumption and satisfying Pareto efficiency. In a two-good model (leisure and consumption), we suggest that the poverty line be increasing in labor time. Our results nevertheless survive a flat poverty line. Similar to Fleurbaey and Trannoy (2003), we show that transferring consumption from the rich to the poor conflicts with Pareto efficiency. Moreover, it conflicts with the ideal of "Responsibility" which is the idea that differences in preferences over leisure-consumption should not justify redistribution. We introduce a logically stronger definition of poverty and prove it to be consistent with Pareto efficiency and Responsibility. Under our definition, an agent is poor if her whole indifference curve is under the poverty line and an agent is rich if her indifference curve lies entirely above it. The goal of transferring consumption from rich to poor does not conflict with Pareto efficiency and Responsibility under the latter definition. We derive a Social Ordering Function satisfying all three ethical goals. The Social Ordering Function is a maximin applied to some specific way of measuring well-being. Moreover, we show that, arbitrarily close to the poverty line, this well-being index is the only way of comparing individuals' well-being consistent with all three objectives in addition to some informational requirements. We derive the optimal income tax under this Social Ordering Function. The optimal income tax schedule exhibits bunching around the

minimum income of a full-time worker. Responsibility leads to negative or zero marginal tax rates on all incomes below this. The shape and level of the poverty line governs optimal marginal tax rates. A steeper poverty line leads to lower marginal tax rates. If the social planner wants to minimize redistribution between individuals above the poverty line, a higher poverty line leads to higher marginal tax rates. We calibrate the optimal income tax to the US economy and perform some comparative statics.

Convergence of First-Order Algorithms for Convex Optimization using Inexact Information

F. Glineur, Y. Nesterov

Université catholique de Louvain,

Center for Operations Research and Econometrics & ICTEAM Institute

e-mail: {francois.glineur,yurii.nesterov}@uclouvain.be

O. Devolder

N-SIDE

e-mail: ode@n-side.com

Discipline: Operations Research

Keywords: Convex Optimization, First-Order Methods, Inexact Oracle, Convergence Analysis, Gradient Method, Accelerated Gradient Method

Standard analysis of first-order methods for convex optimization typically assume availability of exact information, meaning that the values of the objective function and its gradient can be computed exactly at each given point. However, in many situations this assumption does not hold, and only approximate or inexact information can be computed. This is the case when finite differences are used for the gradient, when computations suffer from numerical errors, or when the function itself is computed as the (approximate) optimal value of another auxiliary problem (as is often the case for approaches based on duality or smoothing).

We first present a specific class of inexact first-order oracle, namely the (δ, L) -oracle, which can be viewed as a common extension of the classical notions of epsilon-subgradient and Lipschitz-continuous gradient. We show that such an oracle is naturally available in several situations involving inexact computations, including many standard techniques where an auxiliary problem is solved approximately, such as convex-concave saddle point problems, augmented Lagrangians, and Moreau-Yosida regularization.

We then study the behavior of classical first-order methods for smooth convex optimization when such an inexact oracle is used. In particular, we show that the convergence of the classical gradient method is mostly

unchanged: it is guaranteed to converge to a solution whose accuracy is comparable to that of the oracle. In contrast, the behaviour of the fast gradient method seriously deteriorates: it suffers from error accumulation, is no longer guaranteed to converge and the best accuracy it can reach is much worse than that of the oracle.

Finally, we propose a way to remedy this unsatisfactory situation. We introduce a new method consisting of applying the fast gradient method first during θ steps followed by a modified dual gradient method for the remaining steps. We show that, given an oracle accuracy δ and a target accuracy ϵ unattainable by the fast gradient method, this hybrid method requires a number of steps that is (much) smaller than the classical gradient method. We also show that the optimal switching point θ can be computed in a very simple way: it may be chosen as δ/ϵ , independently of the problem data.

A Globally and Superlinearly Convergent Algorithm for Finding Fixed Points of Nonexpansive Operators

Andreas Themelis

KU Leuven

e-mail: andreas.themelis@student.kuleuven.

Discipline: Operations Research

Almost every convex optimization problem can be cast into a problem of finding a fixed point of a nonexpansive operator, which is typically computed by the Krasnosel'ski-Mann algorithm (KM), namely, relaxed fixed point iterations. This is the usual way of analyzing classical operator splitting techniques such as forward-backward splitting, Douglas-Rachford splitting and ADMM, as well as more recent primal-dual schemes such as the Pock-Chambolle and Vu-Condat splitting methods. These types of algorithms have become extremely popular, especially for large-scale problems, due to their low computational overhead per iteration which compares favorably to interior-point methods, which are the methods of choice for medium scale problems. The price is paid in terms of performance, and in order to obviate the slow convergence and the sensitivity to ill conditioning of the problem some form of preprocessing/preconditioning is needed. In any case, the convergence is Q -linear at best, with Q -factor typically being very close to 1.

In this work we give a new geometric interpretation of KM, thanks to which we develop a generalized scheme which includes KM as a special case and possesses the same global convergence properties and complexity estimates. We then show how we can combine the scheme with quasi-Newton iterations for finding a zero of the fixed point residual. The result is an algorithm which uses exactly the same oracle information as the KM iterations (evaluations of the nonexpansive operator), possesses the same strong global convergence properties and at the same time it asymptotically converges at a superlinear rate. Roughly speaking, the new algorithm can be seen as a way of performing time-varying preconditioning for any opera-

tor splitting method. The theoretical findings are supported by numerical simulations that show how the new algorithm greatly improves upon any classical splitting scheme, even when limited-memory quasi-Newton directions are used. Therefore, the new algorithm can be seen as a step towards transforming operator splitting techniques to reliable, general-purpose, convex optimization solvers for large-scale problems.

Exact Worst-Case Performance of First-Order Methods in Convex Optimization

Adrien B. Taylor, Julien M. Hendrickx

Université catholique de Louvain, ICTEAM

e-mail: Adrien.Taylor@uclouvain.be; Julien.Hendrickx@uclouvain.be

François Glineur

Université catholique de Louvain, ICTEAM/CORE

e-mail: Francois.Glineur@uclouvain.be

Discipline: Operations Research

Keywords: Convex Optimization, Gradient Methods, Convergence Analysis

In this work, we perform algorithmic analysis and design using the *performance estimation* (PE) [2, 4, 5] methodology. The underlying idea of PE is to automatically obtain tight convergence bounds for fixed-step first-order algorithms. That is, to simultaneously obtain worst-case convergence guarantees that may actually occur in practice (i.e., for which there exists a problem reaching it), and a problem on which the algorithm behaves as such.

The PE methodology was born in the original work of Drori [2], which used semidefinite programming (SDP) to improve upon classical known convergence results for several standard first-order optimization algorithms for unconstrained smooth convex programming. In this presentation, we first present the extension developed in [4, 5], which allows obtaining tight convergence bounds in the case of so-called *fixed-step linear gradient methods* [5] — which includes classical gradient methods, accelerated variants, proximal gradient, conditional gradient, subgradient methods, etc.

The SDP approach developed by Drori [2] was also taken further in order to develop a method with optimized performance guarantees in [2, 3]. This algorithm has convergence properties about two times better than standard accelerated methods for smooth unconstrained programming [1]. We also

present a proximal variant to this method, whose gain compared to standard accelerated methods [1] is of the same magnitude.

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Barriers on Symmetric Cones

R. Hildebrand
Weierstrass Institute
e-mail: roland.hildebrand@wias-berlin.de

Discipline: Operations Research

Keywords: semi-definite programming, symmetric cones, barriers

AMS Classification: 90C22, 90C51

Symmetric cones can be characterized in two different manners. On the one hand, these are exactly those regular convex cones which are homogeneous, i.e., possess an automorphism group which acts transitively on their interior, and self-dual. On the other hand, they are the cones of squares in Euclidean Jordan algebras. Symmetric cones have been completely classified, each one being in a unique manner representable as a direct product of irreducible symmetric cones. The latter enjoy a classification into 4 infinite series and an exceptional cone. Symmetric cones possess symmetries which extend to a class of barriers which can be defined on these cones, the self-scaled barriers. This class consists of the non-degenerate convex combinations of the logarithms of the determinants of the irreducible factors. The special properties of the self-scaled barriers are at the heart of the interior-point methods used for solving conic optimization problems over symmetric cones, and thus serve as the base of semi-definite programming.

In this contribution we introduce an analytic description of self-scaled barriers which is of local character and independent of the notion of a symmetric cone. Namely, we identify these barriers as the solutions of a certain quasi-linear fourth-order partial differential equation. Given such a solution in the neighbourhood of some point, it defines and can be extended to the interior of some symmetric cone on which it will represent a self-scaled barrier. This partial differential equation has a simple interpretation as the vanishing of a certain mixed covariant derivative of the metric defined by the Hessian of the solution with respect to the affine connection of the ambient real space and the Levi-Civita connection of the Riemannian

metric defined by this Hessian. More precisely, the third derivative of the solution has to be invariant with respect to the geodesic flow defined by the Riemannian metric. Thus in a certain sense, self-scaled barriers resemble cubic polynomials.

Universal Newton Method

Yurii Nesterov

Université catholique de Louvain, CORE/INMA

e-mail: Yurii.Nesterov@uclouvain.be

Geovani Garpiglia

Federal University of Parana, Brazil e-mail: grapiglia@ufpr.br

Discipline: Operations Research

Keywords: Convex Optimization, Universal Methods, Second Order Schemes

In this talk we present a second-order method for unconstrained minimization of convex functions. It can be applied to functions with Hölder continuous Hessians. Our scheme is a Cubic Regularization of Newton Method, equipped with a special line-search procedure. We prove that the global rate of convergence of this scheme depends continuously on the smoothness parameter. Thus, our method works even for functions with discontinuous Hessian. At the same time, the average number of calls of oracle per iteration is only two.

Network Effects and Oligopolistic Competition

Rabah Amir
University of Iowa
e-mail: rabah-amir@uiowa.edu

Discipline: Economics and Game Theory

This talk deals with symmetric oligopolies with positive network effects for two separate cases: Either there is a single industry-wide network (i.e., compatible products) or each firm has its own proprietary network (i.e., incompatible products). We provide extensive characterization of the properties of Rational Expectations Cournot equilibrium for each setting; in this model, including the comparative statics effects of entry. In addition, we compare the viability and equilibrium outcomes of oligopoly markets with compatible and incompatible networks. We show that viability and production are higher under compatible networks. However, the relationship between equilibrium prices, profits and consumer surplus is ambiguous, but social welfare is always higher in markets with completely compatible networks.

Dynamic Monopoly Pricing of Environmental Goods

Rabah Amir
The University of Iowa
e-mail: rabah-amir@uiowa.edu

Filomena Garcia
Indiana University
e-mail: figarcia@indiana.edu

Joana Resende
University of Porto
e-mail: jresende@fep.up.pt

Discipline: Economics and Game Theory

This paper deals with optimal dynamic pricing for a monopoly that sells an environmental good with the property that consumer's utility is increasing in the discounted accumulated past consumption. In a context of complete information and an infinite-horizon model, we obtain that a monopoly selling the environmental good practices the following pricing strategy. When the peer effects are small, a simple affine price policy is optimal; When the peer effects are strong, it pays for the monopolist to follow a zero mark-up policy in an effort to maximize immediate consumption and create momentum towards building a large consumer base. When the consumer base gets past the critical size, it becomes optimal again for the firm to follow an affine pricing policy (with strictly positive prices thereafter). In this way, early consumers of the environmental good are rewarded for offering critical participation in the firm's effort to build an initial consumer base.

Design of a Responsive Vaccine Chain under Supply and Demand Uncertainty

S. Lemmens

KU Leuven, Research Center for Operations Management

e-mail: stef.lemmens@kuleuven.be

C. J. Decouttere

KU Leuven, Research Center for Operations Management

N. J. Vandaele

KU Leuven, Research Center for Operations Management

M. Bernuzzi

GlaxoSmithKline Vaccines

Discipline: Operations Research

Keywords: Supply Chain Design, Responsiveness, Production Capacity, Guaranteed Service Approach, Vaccine Industry

Supply chain responsiveness is an important and tangible supply chain key performance indicator. We define such a responsive supply chain as a supply chain that is able to meet a fluctuating demand with variable, but relatively short lead times. Ideally, this means that a responsive supply chain is still able to satisfy the customer's demand in case of undesirable variability of the process durations as well as variability stemming from externalities.

Previous research has integrated multi-echelon inventory management into the design of a responsive supply chain by using the guaranteed service approach. We build further upon this work by integrating the production capacity and product flow to capture the supply chain's responsiveness. The production capacity is modeled with a queuing network to handle the variability of the production processes as well as the demand variability. Therefore this work aims to study the trade-offs between supply chain responsiveness, inventories and production capacity for guaranteed service supply chains.

Furthermore, we address the importance of the design of a responsive vaccine supply chain in literature as well as in industry. The vaccine indus-

try is characterized by complex manufacturing processes and stakeholder interactions (e.g. stringent regulatory processes) which tend to be slow. Therefore we embed our model in a broader stakeholder-based supply chain design framework and show our preliminary results of the model application to the Rotavirus vaccine supply chain.

Stability of Networks under Level-K Farsightedness

P. Jean-Jacques Herings

Maastricht University,

e-mail: P.Herings@maastrichtuniversity.nl

Ana Mauleon

Saint-Louis University

e-mail: ana.mauleon@usaintlouis.be

Vincent Vannetelbosch

Université catholique de Louvain

e-mail: vincent.vannetelbosch@uclouvain.be

Discipline: Economics and Game Theory

Keywords: Limited farsightedness, Stability, Networks

JEL Classification: A14, C70, D20

We introduce the concept of a level-K farsighted set to study the influence of the degree of farsightedness on network stability. We show that a level-K farsighted set always exists and that the level-1 farsighted set G_1 is always unique. For generic allocation rules, the set G_1 always contains a level-K farsighted set for any K . We provide easy to verify conditions for a set of networks to be a level-K farsighted set and we consider the efficiency of networks in level-K farsighted sets. We show the tractability of the concept by applying it to a model of criminal networks.

Combinatorial Optimization: The First 50 Years and Beyond

Michel Goemans
Massachusetts Institute of Technology
e-mail: goemans@math.mit.edu

Discipline: Operations Research

In areas such as telecommunications, transportation or manufacturing, combinatorial optimization problems abound, such as the infamous and basic traveling salesman problem. For almost 50 years, we have learned to deal with the computational complexity of these combinatorial problems. In this talk I will review and highlight a few of the core (and CORE!) developments in the field since the birth of CORE. The appetizers will include submodularity, relaxations, convex optimization, approximation algorithms, among other ingredients. As one of the main courses, I would like to describe a surprising connection between social choice and combinatorial optimization, hopefully of interest to this CORE audience, namely between the noise stability of voting schemes and the approximability of the maximum cut problem. For dessert, I will touch upon some emerging new paradigms and some of the challenges ahead.

Introduction to MINLP and its applications; mixed integer conic programming

P. Belotti

Fair Isaac Corp., Xpress Optimizer Dev. Team

e-mail: pietrobeltti@fico.com

Discipline: Operations Research

Keywords: MINLP, mixed integer conic programming

We begin by presenting the general class of mixed integer nonlinear programming (MINLP) problems. MINLP is a very broad class of problems where nonlinear constraints are combined with integrality constraints imposed on some variables, yielding one of the most difficult class of optimization problems.

Its generality is reflected by the variety of real-world applications, of which we outline only a few examples. We also discuss some of the main features of this class of problems and one of the most common methods to solve them, the spatial Branch and bound. This method recursively partitions the set of feasible solutions until it finds an optimum.

In the second part of the talk, we focus on mixed integer conic programming (MICP), a special case of MINLP where all nonlinear constraints are cones. Finding an optimal solution of a MICP requires to find a sufficiently tight convex relaxation of the problem. We present two techniques for identifying such tight relaxations: disjunctive conic programming and nonlinear-based outer approximation.

Integer Polynomial Optimization

Robert Weismantel

ETH Zürich, Department of Mathematics

e-mail: `robert.weismantel@ifor.math.ethz.ch`

Discipline: Operations Research

This talk deals with the problem of optimizing polynomial functions over the lattice points in a polyhedron when the number of variables is a constant.

We explain why the problem is already hard in dimension two for polynomial functions of degree four. Then we will discuss how to solve the problem in polynomial time when the function is a quadratic polynomial in two variables.

Further complexity results about optimizing homogeneous polynomials and cubic polynomials over the integer points in polyhedra in dimension two will be presented too.

In arbitrary but fixed dimension the optimization of a polynomial over the lattice points in a polyhedron remains computationally challenging.

When the polynomial is positive over a polytope, we show that there exists an FPTAS for approximating its maximal value that is based on Barvinok's algorithm for counting the number of lattice points in polyhedra. In order to develop an FPTAS for further classes of nonlinear functions to be minimized over integer points in polyhedra, we propose a framework that combines the techniques of Papadimitriou and Yannakakis with ideas similar to those commonly used to derive certificates of positivity for polynomials over semialgebraic sets. Generally speaking, we work with classes of "basic functions". Then, for a given f , we try to detect a decomposition of f as a finite sum of products of a so-called "sliceable function" and a basic function f_i . Roughly speaking, sliceable functions can be approximated by subdividing the given polyhedron. For instance, the set of all convex functions presented by a first order oracle that are nonnegative over a given polytope could serve as a class of basic functions, because we can solve the

problem for any member in the class in polynomial time when n is fixed. Our technique allows us to prove the following result.

Let Q be a symmetric matrix with integer coefficients and let n be fixed. Then there is an FPTAS for minimizing $f(x) = x^T Q x$ over the integer vectors x in a polytope in the following cases:

1. Q has at most one negative eigenvalue;
2. Q has at most one positive eigenvalue.

The talk is based on four papers that emerged from joint work with the following people: Robert Hildebrand, Raymond Hemmecke, Matthias Köppe, Alberto del Pia, Jesus de Loera and Kevin Zemmer.

Relaxing kindly and efficiently

Jon Lee

University of Michigan, Department of Industrial and Operations Engineering
e-mail: jonxlee@umich.edu

Discipline: Operations Research

Keywords: mixed-integer nonlinear optimization, global optimization, convex relaxation, spatial branch-and-bound

AMS Classification: 90C26

Mixed-Integer Nonlinear Optimization is the mother of all (deterministic) optimization problems. As such, it is too broad a category to do something for in general. Still, there are broad classes where we have positive complexity results and broad (and practically relevant) classes where we have algorithms/software. One of the most successful fairly-general paradigms is “factorable” formulations attacked by sBB (spatial branch-and-bound), as instantiated in software like *Baron*, *Scip*, *Antigone* and *Couenne*. Still, the situation is not that we have extremely reliable nor scalable technology (in sharp contrast with LP and in less sharp contrast to MILP). Indeed, considering some very damning complexity results, we should have modest goals on the computational side. Nonetheless, I will present recent efforts that I have been involved in to make sBB more efficient and robust. Part of this story is closely linked with my initial efforts on nonlinear discrete optimization, catalyzed at CORE, 50/2 years ago. I will explain those aspects as well.

Part of what I will present is joint work with Emily Speakman (U. Michigan). Another part is joint work with Daphne Skipper (U.S. Naval Academy). This research was partially supported by NSF grant CMMI-1160915 and ONR grant N00014-14-1-0315.

Nonlinear Chance-Constrained Problems with applications to Hydro Scheduling

Andrea Lodi

École Polytechnique de Montréal, Montréal, Canada

e-mail: andrea.lodi@polymtl.ca

Enrico Malaguti, Dimitri Thomopulos

Università di Bologna, Bologna, Italy

Giacomo Nannicini

IBM T.J. Watson Research Center, Yorktown Heights, New York, USA

Discipline: Operations Research

Keywords: Nonlinear Programming, Cutting Planes, Uncertainty, Computation

AMS Classification: 90C11, 90C25, 90C57

We present a Branch-and-Cut algorithm for a class of nonlinear chance-constrained mathematical optimization problems with a finite number of scenarios. This class corresponds to the problems that can be reformulated as deterministic convex mixed-integer nonlinear programming problems, but the size of the reformulation is large and quickly becomes impractical as the number of scenarios grows. The Branch-and-Cut algorithm is based on an implicit Benders decomposition scheme, where we generate cutting planes as outer approximation cuts from the projection of the feasible region on suitable subspaces. The size of the master problem in our scheme is much smaller than the deterministic reformulation of the chance-constrained problem. We apply the Branch-and-Cut algorithm to the mid-term hydro scheduling problem, for which we propose a chance-constrained formulation. A computational study using data from ten hydroplants in Greece shows that the proposed methodology solves instances orders of magnitude faster than applying a general-purpose solver for convex mixed-integer nonlinear programming problems to the deterministic reformulation, and scales much better with the number of scenarios. Our numerical

experiments show that introducing a small amount of flexibility in the formulation, allowing constraints to be violated with a joint probability $\leq 5\%$, increases the expected profit by 6.1%.

Do MSRPs Decrease Prices?

In Kyung Kim

Nazarbayev University, Department of Economics

e-mail: in.kim@nu.edu.kz

Babur De los Santos

Clemson University Department of Economics

Dmitry Lubensky

Indiana University, Kelley School of Business

Discipline: Economics and Game Theory

Keywords: Recommended retail price, suggested retail price, list price, non-binding price, search with uncertainty, vertical restraints, resale price maintenance

JEL Classification: L110, L400, L810

The nature of manufacturer's suggested retail prices (MSRPs) and whether their effect is pro- or anticompetitive is not well understood. We exploit a policy experiment in which a ban on MSRPs was imposed and then lifted a year later. Prices increased by 2.3 percent as a result of the ban and decreased by 2.6 percent when the ban was lifted. We find no indication that MSRPs lowered prices by acting as binding price ceilings and outline an alternative mechanism in which recommendations affect prices indirectly by providing information to searching consumers. We demonstrate that recommendations can increase search and reduce prices.

Price Competition in the Presence of a Web Aggregator

Andrea Mantovani
University of Bologna
e-mail: a.mantovani@unibo.it

Oksana Loginova
University of Missouri
e-mail: loginovao@missouri.edu

Discipline: Economics and Game Theory

Keywords: Online reviews aggregators, price discrimination, competition

JEL Classification: C72, D43, D61, L11, L13, M31

Online reviews aggregators and reservation services, such as TripAdvisor, HotelClub and OpenTable help consumers identify the products that best match their preferences. The goal of this study is to understand the impact of a web aggregator on firms and consumers in a horizontally differentiated market. We adopt Salop's circular city model in which consumers initially do not know the locations of the firms in the product space. The firms decide whether or not to be listed on the aggregator's website and choose their prices. When a firm resorts to the aggregator, its location and price become observable to the consumers who visit the website. We consider two different scenarios, depending on the possibility for online firms to offer discounts to the consumers who book online. In the first setting that we consider, the aggregator prohibits restaurants from offering discounts to e-users. In the second, the aggregator allows restaurants to price discriminate between walkers and e-users. In both settings, we compute the equilibrium prices, profits, and the number of online restaurants.

Comparing the equilibrium prices, profits and the number of firms that go online across the scenarios, we derive interesting conclusions from the private and the social standpoints. First, for a given number of online restaurants, we find that allowing discounts may hurt the restaurants. Specifically, when the proportion of e-users in the population is relatively low, online restaurants are trapped in the prisoner's dilemma. Second, we show that uniform pricing induces more restaurants to go online when walkers predominate. When e-users predominate, price discrimination yields a higher number of online restaurants. The socially optimal number of online restaurants can always be reached under price discrimination, provided that the

fixed online fee is sufficiently low. Third, we evaluate the aggregator's optimal policy regarding the fee to be charged and whether to impose uniform pricing or to allow discounts for e-users. Only when the proportion of e-users is relatively low, the aggregator's optimal policy – uniform pricing and a low fee – yields the socially optimal outcome. Hence, the possible intervention by the policy maker to restore efficiency should carefully consider the interplay between the fee and the pricing policy adopted by the aggregator.

Disentangling the Effect of Trade Agreements on Trade

S. Standaert
SHERPPA

Ghent University, Department of Economics
e-mail: samuel.standaert@ugent.be

G. Rayp
SHERPPA

Ghent University, Department of Economics
e-mail: glenn.rayp@ugent.be

Discipline: Econometrics

Keywords: Endogenous Trade Agreements, Gravity Equation, Qualitative Choice Models, Qualitative VAR

JEL Classification: C11, C25, F14, F15

While the endogeneity of trade and regional integration agreements was established early on, this issue has only been addressed explicitly in gravity models during the last decade and a half. Initial attempts using instrumental variables proved unreliable, causing authors to look for alternative solutions (e.g. non-parametric matching techniques). This paper brings together the literature on both gravity equations explaining trade, and the probit regressions explaining the probability of an integration agreement. This is done by estimating them simultaneously using a qualitative vector autoregression model. The regional integration agreement dummy variable is first defined in terms of a latent equivalent: the *willingness to sign an agreement*. This continuous latent variable can subsequently be modeled as endogenous with trade using a normal VAR model. Estimation relies on Bayesian Gibbs sampling.

The qualitative VAR uses the dynamic behavior of the endogenous variables to identify their long-run interaction. This allows us to estimate the effect of both variables without running afoul of any logical inconsistencies that pose a problem in cross-sectional studies. Furthermore, it allows the

endogenous nature of other control variables like the GDP or the capital-labor ratio to be taken into account. To our knowledge, this is the first time a qualitative VAR has been used to analyze the effect of trade agreements.

Our preliminary findings confirm that an increase in trade raises the probability of an agreement and vice versa, although the response can differ over specific continents. Overall, we find a relatively small average treatment effect of RIAs: trade increases with 10% after one year and 40% after five years, whereafter it slowly rises to 80% after 35 years.

New Media Platforms, Copyright Owners and Advertising

E. Carroni

ThEMA-Université de Cergy Pontoise

e-mail: carronielias@gmail.com

D. Paolini

Università di Sassari, DiSea, CRENoS and CORE

e-mail: dpaolini@uniss.it

Discipline: Economics and Game Theory

Keywords: Platform, Online Streaming, Advertisement

JEL Classification: D43, L13, L82

We analyze the optimal decisions of an online streaming platform interacting with different groups of agents. First, contents are obtained through a negotiation with a copyright owner (CO), who is paid per-click. Second, the platform may decide to attract advertisers. Third, the contents can be offered to users either free-of-charge (*basic subscription* with ads) or free-of-commercial (*premium subscription*). Users are heterogeneous according to the level of aversion against advertisement. When the platform's bargaining power is relatively strong in relation to CO, we find that the streaming service finds it optimal to offer only a *premium subscription* without displaying any ad. Oppositely, a weaker bargaining power results in the offer of a menu of subscriptions, with ad-intolerant users subscribing *premium* and moderately averse users opting for the *basic*. Our findings are in line with the observation of different offers of online streaming outlets, which offer the *premium*-only when their brand is already well-established whereas offer also a *basic* subscription when they have to launch a brand-new service.

Wrong Politicians

Alessandro Fedele
Free University of Bozen/Bolzano
e-mail: alessandro.fedele@unibz.it

Pierpaolo Giannoccolo
University of Bologna

Discipline: Economics and Game Theory (Political Economy)

Keywords: Politicians' remuneration, Political selection, Skills, Motivations, Welfare

JEL Classification: P16, J45, J24, J32, I3

How do wage and other financial benefits affect the type of people attracted to politics? This paper answers the question by studying selection into politics of individuals with heterogeneous skills and heterogeneous motivations. To this aim, a three-period citizen-candidate model is developed. In the first period, potential candidates observe the level of politicians' remuneration and then play a candidacy game by deciding simultaneously whether to run for office; the candidacy game is an incomplete information game because the motivational type of potential candidates is assumed to be private information. In the second period, an election takes place and only one candidate is elected. In the third period, the successful candidate provides a public good on behalf of all individuals; all the others devote themselves to a private activity in the market sector. A benchmark analysis where skills are the only relevant characteristic is initially proposed. Findings show that welfare is increasing in the politicians' wage since the best, i.e., high-skilled, individuals are attracted to politics only if the remuneration covers their large opportunity costs. This result is in line with the existing literature concerning the effect of remuneration on political selection.

The general setup where motivation is also considered is then investigated and welfare is shown to be maximized when the wage is relatively low. The intuition is that high-skilled individuals with market-oriented rather than public-spirited motivation, i.e., the "wrong" sort of individuals, are crowded out.

A Political Economy Model of Immigration

M. Morelli

Bocconi University, Department of Policy Analysis and Public Management

e-mail: massimo.morelli@unibocconi.it

M. Negri

University of St. Andrews

School of Economics and Finance

e-mail: mn48@st-andrews.ac.uk

Discipline: Economics and Game Theory

We study the impact of political institutions on immigration policies, specifically openness and extension of welfare rights to immigrants. Following the seminal work of Austen-Smith (2000), we construct a model with heterogeneous productivity and endogenous occupational choice. Immigration policies affect aggregate and individual income by altering the incentives behind occupational choices. We study the effect of different electoral systems in a context where immigration policies and taxation are determined by social (occupational) classes and political parties through elections.

VAT Notches

Li Liu

University of Oxford, Centre for Business Taxation

e-mail: li.liu@sbs.ox.ac.uk

Ben Lockwood

University of Warwick, Department of Economics and CBT, CEPR

e-mail: b.lockwood@warwick.ac.uk

Discipline: Economics and Game Theory

We develop a conceptual framework which captures the effect of the VAT system on profit by two effective taxes. This allows (i) predictions of the determinants of voluntary registration and bunching at the registration threshold; (ii) develops a formula for estimating the elasticity of value-added with respect to the statutory tax. We bring the theory to the data, using linked administrative VAT and corporation tax records in the UK from 2004-2009. Consistently with the theory, voluntary registration is positively related to the intensity of input use and negatively related to the share of B2C transactions. There is bunching at the VAT threshold, and the amount of bunching is negatively related to the intensity of input use and positively related to the share of B2C transactions, again consistently with the theory. We provide an estimate of the elasticity of the VAT tax base in the range of 0.09 and 0.18.

Optimal Policies against Profit Shifting: The Role of Controlled-Foreign-Company Rules

Andreas Haufler

University of Munich, Department of Economics

e-mail: Andreas.Haufler@econ.lmu.de

Mohammed Mardan

ETH Zurich, Department of Management, Technology and Economics

Dirk Schindler

NHH Bergen, Department of Accounting, Auditing and Law

Discipline: Economics and Game Theory

Keywords: multinationals, profit shifting, controlled foreign company rules

JEL Classification: H25, H73, F23

By introducing controlled-foreign-company (CFC) rules, the parent country of a multinational firm reserves the right to tax the income of the firm's foreign affiliates if the tax rate in the affiliate's host country is below a specified threshold. We identify the conditions under which binding CFC rules are part of the optimal tax mix when governments can set the statutory tax rate, a thin capitalization rule and the CFC rule. We also analyze the effects of economic and financial integration on the optimal policy mix. Our results correspond to the actual development of anti-avoidance rules in OECD countries.

Immobilizing Corporate Income Shifting: Should It Be Safe to Strip in the Harbor?

Thomas A. Gresik
University of Notre Dame
e-mail: tgresik@nd.edu

Dirk Schindler
Norwegian School of Economics
e-mail: dirk.schindler@nhh.no

Guttorm Schjelderup
Norwegian School of Economics
e-mail: guttorm.schjelderup@nhh.no

Discipline: Economics and Game Theory

Keywords: Multinational, income-shifting, safe harbor, earnings stripping

JEL Classification: H73, H26, K34

Many subsidiaries can deduct interest payments on internal debt from their taxable income. By issuing internal debt from a tax haven, multinationals can shift income out of host countries through the interest rates they charge and the amount of internal debt they issue. We show that, from a welfare perspective, thin-capitalization rules that restrict the amount of debt for which interest is tax deductible (safe harbor rules) are inferior to rules that limit the ratio of debt interest to pre-tax earnings (earnings stripping rules), even if a safe harbor rule is used in conjunction with an earnings stripping rule.

Corporate Taxes and Firm Behavior - Evidence from South Africa

Nadine Riedel

Ruhr Universität Bochum

e-mail: nadine.riedel@rub.de

joint work with Collen Lediga and Kristina Strohmaier

Discipline: Economics and Game Theory

The aim of this paper is to empirically investigate firm behavior in response to corporate taxation and administrative deterrence instruments (tax payer auditing) in a low enforcement environment. Using the population of corporate tax returns in South Africa for 2008-2015, we in a first step analyze bunching in the distribution of taxable income at kinks and notches in the tax schedule and estimate the elasticity of corporate taxable income with respect to statutory corporation tax rates. The analysis yields large elasticity estimates suggesting that corporate taxpayers react sensitively to tax incentives. Detailed information on tax payer audit results, tax deductions and asset investment moreover allows us to distinguish real and evasion responses to taxation. In a second step, we use audit data to study the response of tax payers to deterrence instruments and analyse a large-scale administrative intervention that aimed at bringing non-registered tax payers into the tax net.

Patent Boxes Design, Patents Location and Local R&D

Annette Alstadsæter

University of Oslo

Salvador Barrios

European Commission, Joint Research Centre, IPTS

Gaetan Nicodeme

European Commission, ULB, CESifo and CEPR

e-mail: Gaetan.Nicodeme@ec.europa.eu

Agnieszka Maria Skonieczna

European Commission

Antonio Vezzani

European Commission, Joint Research Centre, IPTS

Discipline: Economics and Game Theory

Keywords: Corporate taxation, patent boxes, location, patents, R&D, nexus approach

JEL Classification: F21, F23, H25, H73, O31, O34

Patent boxes have been heavily debated for their role in corporate tax competition. This paper uses firm-level data for the period 2000-2011 for the top 2,000 corporate R&D investors worldwide to consider the determinants of patent registration across a large sample of countries. Importantly, we disentangle the effects of corporate income taxation from the tax advantage of patent boxes. We also exploit a new and original dataset on patent box features such as the conditionality on performing research in the country and their scope. We find that patent boxes have a strong effect on attracting patents mostly due to their favourable tax treatment, especially so for high quality patents. Patent boxes with a large scope in terms of tax base definition have also stronger effects on the location of patents. The size of the tax advantage offered through patent box regimes are found to deter local innovative activities while R&D development conditions tend to attenuate this adverse effect. Our simulations show that on average coun-

tries imposing such development conditions tend to grant a tax advantage which is slightly larger than optimal from a local R&D impact perspective.

A Diagnostic Criterion for Approximate Factor Structure

Patrick Gagliardini

University of Lugano and Swiss Finance Institute,
e-mail: patrick.gagliardini@usi.ch

Elisa Ossola

European Commission - Joint Research Centre,
e-mail: elisa.ossola@jrc.ec.europa.eu

Olivier Scaillet

University of Geneva and Swiss Finance Institute,
e-mail: olivier.scaillet@unige.ch

Discipline: Econometrics

Keywords: large panel, approximate factor model, asset pricing, model selection

JEL Classification: C12, C13, C23, C51, C52, C58, G12

We build a simple diagnostic criterion for approximate factor structure in large cross-sectional equity datasets. Given a model for asset returns with observable factors, the criterion checks whether the error terms are weakly cross-sectionally correlated or share at least one unobservable common factor. It only requires computing the largest eigenvalue of the empirical cross-sectional covariance matrix of the residuals of a large unbalanced panel. A general version of this criterion allows us to determine the number of omitted common factors. The panel data model accommodates both time-invariant and time-varying factor structures. The theory applies to generic random coefficient panel models under large cross-section and time-series dimensions. The empirical analysis runs on returns for about ten thousand US stocks from January 1968 to December 2011 for several time-varying specifications. Among several multi-factor time-invariant models proposed in the literature, we cannot select a model with zero factors in the errors. On the opposite, we conclude for no omitted factor structure in the errors for several time-varying specifications.

Forecasting Stock Returns with Large Dimensional Factor Models

A. Giovannelli

Università di Roma Tor Vergata

e-mail: alessandro.giovannelli@uniroma2.it

D. Massacci

Bank of England

e-mail: dm355@cantab.net

S. Soccorsi

ECARES, Université Libre de Bruxelles

e-mail: stefano.soccorsi@ulb.ac.be

Discipline: Econometrics

Keywords: factor models, large data sets, stock return forecasting.

JEL Classification: C38, C55, C58, C53, G17.

A vast literature surveyed in Rapach and Zhou (2013) dealt with stock returns forecasting; we assess the predictive power of large dimensional factor models. Inspired by the also voluminous literature on macroeconomic variables forecasting with large-dimensional datasets (Stock and Watson, 2002; Forni, Hallin, Lippi and Reichlin, 2003; Bai and Ng, 2008; among others), we investigate whether the information arising from a large number of predictors may be successfully employed to forecast stock returns: to the very best of our knowledge, this is a largely unexplored research question.

We employ the novel FRED-MD dataset of macroeconomic variables described in McCracken and Ng (2015) and condensate its information following three different approaches to dynamic factor models. The first one is the popular static method (Stock and Watson, 2002) which has been applied to stock return forecasting by Ludvigson and Ng (2007). We compare it with other two approaches ignored by this literature: the restricted dynamic method of Forni, Hallin, Lippi and Reichlin (2005) and the fully dynamic method of Forni, Hallin, Lippi and Zaffaroni (2015) which allows for an infinite dimensional factor space.

Our results may be summarized as follows:

- (i) The dynamic approaches outperform the static (and a random walk benchmark).

- (ii) Rolling window forecast are more accurate during recessions while recursive window forecast are more accurate during expansions.
- (iii) The information in factor model estimation is a key issue. Large dataset forecasts are more accurate than those obtained with variable selection approaches: either statistical selection through the LASSO operator (with various degrees of sparsity) and theoretical considering the variables selected by Goyal and Welch (2008).

Models of Financial Return With Time-Varying Zero-Probability

Genaro Sucarrat

BI Norwegian Business School, Department of Economics

e-mail: genaro.sucarrat@bi.no

Steffen Grønneberg

BI Norwegian Business School, Department of Economics

Discipline: Econometrics

Keywords: Intraday data, financial return, volatility, GARCH, log-GARCH, ACL, exchange rates

JEL Classification: C01, C13, C14, C22, C25, C32, C51, C52, C58

The probability of an observed financial return being equal to zero is not necessarily zero. This can be due to price discreteness or rounding error, liquidity issues (e.g. low trading volume), market closures, data issues (e.g. data imputation due to missing values), characteristics specific to the market, and so on. Moreover, the zero-probability may change and depend on market conditions. In common models of return volatility, however, e.g. ARCH, SV and continuous time models, the zero-probability is zero, constant or both. We propose a new class of models that allows for a time-varying zero-probability, and which can be combined with standard models of return volatility: They are nested and obtained as special cases when the zero-probability is constant and equal to zero. Another attraction is that the return properties of the new class (e.g. volatility, skewness, kurtosis, Value-at-Risk, Expected Shortfall) are obtained as functions of the underlying volatility model. The new class allows for autoregressive conditional dynamics in both the zero-probability and volatility specifications, and for additional covariates. Simulations show parameter and risk estimates are biased if zeros are not appropriately handled, and an application illustrates how the biases affect risk-estimates in practice.

Back to the Future: Infrastructure and Landscape Feedbacks in Urban Simulation Models

Geoffrey Caruso
University of Luxembourg
e-mail: geoffrey.caruso@uni.lu

Pierre Frankhauser
Université de Franche-Comté

Dominique Peeters
CORE, Université catholique de Louvain

Isabelle Thomas
CORE, Université catholique de Louvain

Gilles Vuidel
Université de Franche-Comté

Discipline: Human and Economic Geography

Geocomputational models, particularly Cellular Automata (CA) and Agent-Based Models (ABM) have been used over the last 20 years to generate urbanisation patterns with the aim to replicate observed urban expansion footprints. In applied cases, with the addition of land use or network constraints, simulation models seem to perform rather well and lead to sound urban patterns. Models that are more parsimonious in parameters and models with explicit micro-economic component however seem to lag behind: the spatial outcome of these models is too homogenous to resemble real cities, despite agglomeration and dispersion processes at neighbourhood scale (e.g. related to endogenous open space externalities) and despite the self-emergence of road networks. Rather than resolving to exogenous polycentric setting or exogenous stochasticity, we investigate this insatisfaction by exploring a theoretical 2D micro-economic simulation model where the total length of the road infrastructure network feeds back into households' budget and their decision, and where the households who settled previously refuse utility losses resulting from a further urbanisation of their neighbourhood. These changes are computationally demanding since all alternative location decisions and impacts, at one particular time, need to be simulated prior to making a time move in the model. This is a substantial departure to urban CA models where patterns at time t are only influenced by patterns at $t - 1$, i.e. where the effects (feedbacks at t)

of one own's location is not considered at time t . In this paper we explore the effects of these feedbacks on equilibrium urban morphologies.

Spatial Development Potential in Flanders based on Transit Node Value and Service Level

G. Engelen, E. Verachtert, I. Mayeres, L. Poelmans,
M. van der Meulen and M. Vanhulsel

VITO - Flemish Institute for Technological Research, Environmental Modelling Unit
e-mail: guy.engelen@vito.be

Discipline: Human and Economic Geography

Settlement areas occupy 32.7% of Flanders' territory. This positions Flanders at the absolute top in Europe. Currently, the settlement area grows at a rate of some 6ha/day. In its new Spatial Policy Plan, the Flanders' government aims at putting a halt at this expansion. One of the guiding spatial planning principles is to concentrate development on locations within a distance that can be covered on foot or bicycle from nodes on the public transportation system, and, equipped with a high level of services. In order to assess the spatial development potential, an elaborate modelling exercise was carried out resulting in a typology classifying every 1ha location in Flanders in one of 16 types with respect to, on the one hand the transit node value, and on the other the service level. To the effect, Flanders is modelled as a rectangular grid of 1,350,000 cells measuring 1 ha each. With respect to the transit node value, five indicators of the SNAMUTS framework were computed for all nodes of the rail networks consisting of trains, metro, and tramways and the A-lines of the public bus company. In addition a slow traffic density indicator expressing the density of walking and bicycling paths in a radius of 3.75km area around each node was computed. The resulting six indicators were aggregated in a composite indicator. Next, the node value of every 1 ha cell was estimated by applying a shortest path and distance decay calculation on foot and bicycle paths extending from each node. With respect to the service level, the location of every single service point pertaining to some 40 different types of services was mapped. Services of 4 different types are distinguished: education,

culture and sports, residential support, and, health and social care. Depending on the frequency at which they are needed and the area serviced, they were further classified into basic, regional and metropolitan. Again, the service level of every 1 ha location was computed by applying shortest path and distance decay calculations. Moreover, in every 1 ha location marginal utility was applied to aggregate the various services of the same type, thus taking into account the excess of choice.

For both, transit node value and service level, the resulting cell values are classified in one of 4 classes by means of Jenks' natural breaks method: poor, limited, good and very good. By combining both, 16 types can be distinguished. The 16 types are overlaid with other information, such as: population, households, employment, zoning status, settlement area, etc. with a view to detect areas featuring growth potential.

Land Use and Density in the European City: Monocentric Analysis and Scaling

Rémi Lemoy and Geoffrey Caruso

University of Luxembourg, Maison des Sciences Humaines,
11 Porte des Sciences, L-4366 Esch-Belval, Luxembourg
e-mail: remilemoy@gmail.com, geoffrey.caruso@uni.lu

Discipline: Human and Economic Geography

Keywords: urban land use, monocentric analysis, housing

JEL: R14, R31, C55

In this work we study the profile of land use and population density in European cities with respect to the distance to the city centre. More specifically we address the scaling of land use and density curves with respect to city population and rely on fine grained land use data. Our main objective is to retrieve generic laws that can support the calibration of monocentric urban economic models for European cities.

We use the GMES Urban Atlas database, providing a precise description of land use at 5m resolution in the 305 major European urban areas (more than 100.000 inhabitants). We combine this dataset with population density from the Geostat population grid, which covers the whole of European Union (EU) with a 1km² resolution. Population is allocated proportionally to surface and weighted by soil sealing and density classes of the GMES data.

We analyse the evolution with distance to the city centre, which we define for convenience as the location of the city hall, of population density and of the share of land used for different purposes: housing, roads, railways, urban green, water, agriculture, forest. To this end, we define concentric rings of fixed width around the city centre, in which we average each land use and population.

In order to compare different cities and to identify a global picture, i.e. a standard representative European city, we study scaling relationships for the obtained monocentric land use shares and density curves. We analyse

the scaling of these curves with respect to city population, following similar approaches conducted in the literature for different parameters (such as income or road space). The total population for each city is computed from the population grid.

We find that land use curves, in particular housing and roads shares, tend to scale like the square root of city population. Population curves have roughly exponential shapes, as it has been widely modelled in the literature, although usually not based on land use and soil sealing data. Population curves tend to scale like the city population to a power close to $1/3$.

These results allow us to propose a simple monocentric description of land use shares and population curves in a representative European city, whose size can be chosen based on the scaling relationships we obtain. This result is especially interesting, and of practical use, for the purpose of calibration and validation of monocentric urban models, that can differentiate (or not) housing from land and include interactions between non-developed and developed land.

A Novel Approach to Group Decision-Making: Applying Majority Judgment Over Polyhedral Sets

Michael O. Ball

Robert H Smith School of Business & Institute for Systems Research
University of Maryland
College Park, MD 20742 USA
e-mail: mball@rhsmith.umd.edu

joint work with Cindy Barnhart, Prem Swaroop, Vikrant Vaze and Chiwei Yan

Discipline: Operations Research

Keywords: Voting, Group Decision Making, Integer Programming

We describe new methods in group decision making by extending the *Majority Judgment* ranking method to handle a candidate space of infinite size. Specifically, the candidate space is modeled as a polyhedral set. The output of the process is a member of the candidate space chosen based on inputs from a group of decision makers while using certain optimization models that employ the Majority Judgment criterion. Two approaches are developed. The first approach relies on multiple rounds of grading (or voting) and iterative candidate generation. The candidate generation employs a novel integer programming model. The second approach employs a robust optimization framework and only takes as input each decision maker's most preferred candidate. The vector output is the candidate that has the best worst-case guarantee in terms of majority grade. We demonstrate the effectiveness of our approaches through two case studies involving group decision making: 1) a capital budgeting problem; and 2) a strategic air traffic flow management problem.

Optimizing Over Unrooted Binary Trees

Daniele Catanzaro
Louvain School of Management
Center for Operations Research and Econometrics
Université catholique de Louvain (UCL)
email: `daniele.catanzaro@uclouvain.be`

Discipline: Operations Research

Keywords: Network Design, Polyhedral Combinatorics, Combinatorial Optimization, Mixed Integer Linear Programming, Branch-Price-and-Cut

Recent results on the combinatorial properties of Unrooted Binary Trees (UBTs) have shown unexpected connections between a particular class of \mathcal{NP} -hard combinatorial optimization problems defined over them and classical optimization problems such as the Traveling Salesman Problem (TSP) and the Quadratic Assignment Problem (QAP). These connections proved to be of remarkable assistance both to decide the complexity of (some of) the problems belonging to this class and to develop a number of exact algorithms to solve instances from this class previously unsolvable. In this talk we introduce to the general problem of optimizing over UBTs, we review the Parsimony Phylogeny Estimation Problem (PPEP) and the Minimum Evolution Problem (MEP), and we present a number of recent advances concerning their exact solution.

A Branch-and-Price Algorithm for the Parsimonious Loss of Heterozygosity Problem

L. Porretta

Univesrité Libre de Bruxelles (ULB), Département d'Informatique
e-mail: lporrett@ulb.ac.be

D. Catanzaro

Univesrité Catholique de Louvain (UCL), Louvain School of Management
e-mail: daniele.catanzaro@uclouvain.be

B. V. Haldórsson

Reykjavk University, School of Science and Engineering
e-mail: bjarnivh@ru.is

B. Fortz

Univesrité Libre de Bruxelles (ULB), Département d'Informatique
e-mail: bfortz@ulb.ac.be

Discipline: Operations Research

Keywords: Clique Partitioning, Interval Graphs, Branch-and-Price, Computational Biology, Genome-Wide Association Studies

AMS Classification: 90C11, 90C27

The *Parsimonious Loss of Heterozygosity Problem* (PLOHP) is a \mathcal{NP} -hard combinatorial optimization problem arising in computational biology. The problem consists of finding a minimum cost clique covering in a particular kind of interval graph called *Max-Point Tolerance Graph* (MPTG). The optimal solution to an instance of the PLOHP proves of fundamental support in genome-wide association studies as it allows the association of major human diseases with chromosomic regions from patients that underwent to loss of heterozygosity events. In this article we build on Catanzaro *et al.*' seminal work and present an integer linear programming formulation for the PLOHP based on column generation. We introduce a number of preprocessing techniques to reduce the size of a given instance of the problem and we present decomposition strategies to divide a reduced instance into independent subproblems of even smaller size. We develop a new efficient algorithm to find maximum node-weighted cliques in MPTGs. We

embody this algorithm in a Branch-and-Price algorithm for the PLOHP, whose computational performance are 10-30x faster than the previous approach described in the literature.

Double Machine Learning for Causal and Treatment Effects

V. Chernozhukov
MIT, Department of Economics
e-mail: vchern@mit.edu

M. Demirer
MIT, Department of Economics

D. Chetverikov
UCLA, Department of Economics

E. Duflo
MIT, Department of Economics

C. Hansen
University of Chicago, Booth School of Business

W. Newey
MIT, Department of Economics

Discipline: Econometrics

Most supervised machine learning (ML) methods are explicitly designed to solve prediction problems very well. Achieving this goal does not imply that these methods automatically deliver good estimators of causal parameters. Examples of such parameters include individual regression coefficients, average treatment effects, average lifts, and demand or supply elasticities. In fact, estimates of such causal parameters obtained via naively plugging ML estimators into estimating equations for such parameters can behave very poorly, for example, by formally having inferior rates of convergence with respect to the sample size n caused by regularization bias. Fortunately, this regularization bias can be removed by solving auxiliary prediction problems via ML tools. Specifically, we can form an efficient score for the target low-dimensional parameter by combining auxiliary and main ML predictions. The efficient score may then be used to build an efficient estimator of the target parameter which typically will converge at the fastest possible $1/\sqrt{n}$ rate and be approximately unbiased and normal, and from which valid confidence intervals for these parameters of interest may be constructed. The resulting method thus could be called a “double ML” method because it relies on estimating primary and auxiliary predictive models. Such double ML estimators achieve the fastest rates of

convergence and robustness of behavior with respect to a broader class of probability distributions than naive "single" ML estimators. We illustrate the use of the proposed methods with an application to estimating the effect of 401(k) eligibility on accumulated assets.

Unemployment Cycles

Jan Eeckhout
University College London
e-mail: j.eeckhout@ucl.ac.uk

Ilse Lindenlaub
Yale

Discipline: Economics and Game Theory

The labor market by itself can create cyclical outcomes, even in the absence of exogenous shocks. We propose a theory that shows that the search behavior of the employed has profound aggregate implications for the unemployed. There is a *strategic complementarity* between active on-the-job search and vacancy posting by firms: active search changes the number of searchers and the duration of a job, and in the presence of sorting, it improves the quality of the pool of searchers. More vacancy posting in turn makes costly on-the-job search more attractive, a self-fulfilling belief. The absence of on-the-job search discourages vacancy posting, rendering costly on-the-job search unattractive. This model of multiple equilibria can account for large fluctuations in vacancies, unemployment, and job-to-job transitions; it provides a rationale for the Jobless Recovery through a novel channel of the employed searchers crowding out the unemployed; and it gives rise to a shift in the Beveridge Curve (the unemployment-vacancy locus). Each of these phenomena is matched in the data.

Endogenous Credit and Investment Cycles with Asset Price Volatility

Francesco Carli

UCP, Católica Lisbon School of Business and Economics

Leonor Modesto

UCP, Católica Lisbon School of Business and Economics and IZA

Discipline: Economics and Game Theory

Keywords: Credit Frictions, Limited Commitment, Indeterminacy, Sunspots.

JEL Classification: E32, E44

It is commonly accepted that credit market frictions are an important source of macroeconomic fluctuations. But what is the link between the two? And what is the driving factor of asset prices volatility? To answer these questions we have introduced a specific credit friction, limited commitment, in a general equilibrium model with production and investment in productive capital, where agents can trade bonds. The model always displays a stationary equilibrium where bonds are traded. In addition, a stationary equilibrium with no bonds may also exist. More importantly, limited commitment may generate stochastic endogenous fluctuations driven by self-fulfilling volatile expectations (sunspots), yielding credit and investment cycles and bond price volatility consistent with data.

Undervaluation, Social Optimum, and Growth

Karine Gente

Aix-Marseilles Universite, Aix-Marseilles School of Economics

Miguel León-Ledesma

University of Kent, School of Economics and MaGHiC

e-mail: m.a.leon-ledesma@kent.ac.uk

Carine Nourry

Aix-Marseilles Universite, Aix-Marseilles School of Economics

Discipline: Economics and Game Theory

Keywords: undervaluation, growth, financial constraints

JEL Classification: O41, F43

Can a strategy of undervaluing the real exchange rate affect the equilibrium growth rate? We study a two-sector OLG endogenous growth model of an open economy where the country faces a collateral constraint on borrowing. If only tradable output can be collateralized, an expansion of this sector relaxes the economy-wide collateral constraint leading to higher aggregate capital and growth. This constitutes an externality that drives a divergence between the social optimum and the constrained efficient allocation. A tax policy akin to a devaluation can increase growth. This, however, is not the case if aggregate output can be collateralized. We discuss the implications of the model for recent empirical debates on the growth-enhancing effects of real exchange rate undervaluation.

On Private Capital Falling into Public Domain

Julio Dávila

Université catholique de Louvain, CORE

e-mail: julio.davila@uclouvain.be

Discipline: Economics and Game Theory

The fact that some private capital eventually slides into the public domain (e.g. taxes on household savings and income channeled to public infrastructures, or R+D investments as patents expire) inefficiently distorts downwards the capital accumulation. This is established for both infinitely-lived agents and overlapping generations setups. I provide next a tax and transfers balanced policy able to decentralize the planner's steady state without resorting to the impracticable all-encompassing extension of property rights otherwise needed to address the problem. It consists of (i) subsidizing the rental rate of capital by an amount equal to the depreciation/obsolescence rate of the capital sliding into the public domain, and (ii) taxing households debt issued against future dividends.

Consistent Estimation of Linear Regression Models Using Matched Data

Masayuki Hirukawa

Setsunan University, Faculty of Economics

e-mail: hirukawa@econ.setsunan.ac.jp

Artem Prokhorov

University of Sydney, Business School

e-mail: artem.prokhorov@sydney.edu.au

Discipline: Econometrics

Often economists must employ two different data sets to obtain all the variables necessary for their analyses. When they encounter this problem, they typically proceed to constructing combined samples via the nearest neighbor matching (“NNM”) that exploits proximity of the common variable(s) across the two data sets. For example, in important income surveys, numerous earnings records are missing, and the missing observations are imputed via a version of the NNM. In the study of returns to schooling, while a worker’s earnings and individual characteristics are available in an income survey, a variable representing his/her ability (e.g., test scores) can be found only in a psychometric data set. The NNM is then used to merge two data sets.

In this paper we study estimation issues of a linear regression model using the matched samples. It is demonstrated that the ordinary least squares (“OLS”) estimator based on the matched samples is inconsistent. Moreover, the convergence rate of the OLS estimator to its probability limit may not be the parametric one. To be more precise, the NNM generates two different bias terms, namely, the first-order non-vanishing and second-order asymptotically negligible biases. The former, viewed as a measurement error bias, leads to inconsistency in OLS. On the other hand, the convergence rate of the latter depends of the number of the common variables across two samples, and it becomes a nonparametric one when the number is three or more.

However, it is possible to correct the bias nonparametrically as long as the common variables are few. We propose two semiparametric bias-corrected estimators and explore their asymptotic properties. The first, one-step estimator is designed exclusively for the case of a single common variable. The second, two-step estimator is intended for the cases of two or three common variables. Its bias correction procedure is reminiscent of that of the fully modified least squares estimation for cointegrating regressions. Indeed, the estimator ensures consistency by removing the first-order bias in the first step, and it eliminates effect of the second-order bias asymptotically in the second step. Both estimators can be interpreted as indirect inference estimators, and they are shown to be \sqrt{n} -consistent and asymptotically normal. Furthermore, Monte Carlo simulations confirm that both estimators successfully eliminate the bias generated by the NNM.

Limited Information Maximum Likelihood Estimation of the Random Coefficients Demand Model

Thi Thu Hien Pham

KU Leuven

e-mail: thithuhien.pham@kuleuven

Discipline: Econometrics

Keywords: Random coefficients logit, aggregate data, limited information, maximum likelihood estimation, reparameterization

Berry, Levinsohn and Pakes (1995) include random coefficients in the logit demand function to explain the heterogeneity of consumers' preference of differentiated products. This model, however, doesn't require that all of the random coefficients exhibit high variation. In other words, one or more of the standard deviations can be very close to or equal to zero which is the boundary of its parameter space. Examples in which some standard deviations are very close to zero or statistically insignificant can be found in empirical works or simulation settings (see Nevo (2000), Reynaert and Verboven (2014)). Identification difficulty arises for the GMM estimator since the rank condition doesn't hold.

Our proposed approach is to use the limited information maximum likelihood estimator (hereafter referred to as LIML) coupled with the reparameterization of the variation parameters. The LIML estimator was first introduced in Rubin and Anderson's (1949) paper. Their idea is to break up the system of structural equations into small subsystems and concentrate solely on the estimation of the parameters of the subsystem of interest using the maximum likelihood method. Another virtue of the LIML estimator is that the likelihood function is invariant under reparameterization. This allows us to use the square root of the variance instead of the standard deviation as seen in the BLP model. In addition, the LIML estimator has been shown to have more favorable properties than the other instrumental variable estimators. For example, it produces estimates with smaller bias,

leading to more accurate inference (see Rothenberg (1983), Donald and Newey (1999)).

This paper presents the details of the formulation and implementation of the LIML estimation using Dubé, Fox and Su's (2012) Mathematical Program with Equilibrium Constraints (MPEC) method. The use of the MPEC method reduces the computational time significantly and mitigates the convergence problems. The paper also includes a discussion on the identification conditions and the asymptotic properties of the LIML estimator in the context of the BLP model involving both linear and nonlinear parameters. Different Monte Carlo studies are carried out with different specifications for the data generating process to examine the performance of the LIML estimator and compare it with the GMM estimator. The results show that the LIML estimator based on the transformed parameters performs well. In the cases where the true variation parameters are set very close to zero, the LIML estimator even outperforms the GMM estimator. In general, the behaviors of the LIML estimator are consistent with what is expected by the asymptotic theory discussed in this paper.

Is the Pearson Sample Correlation Coefficient as Feasible as You Think?

Cindy S.H. Wang

Université catholique de Louvain, CORE

National Tsing Hua University, Taiwan, Department of Quantitative Finance

e-mail: cindywang9177@gmail.com

Wan Yi Lee

National Tsing Hua University, Taiwan, Department of Quantitative Finance

Cheng Hsiao

University of Southern California, U.S.A., Department of Economics

Hong Kong University of Science and Technology

Xiamen University, WISE

Discipline: Econometrics

Keywords: Fractionally integrated process, autoregressive approximation, spurious regression, correlation tests, imbalanced regression, financial contagion and interdependence

Abstract¹ This paper re-examines the consistency of conventional Pearson cross-correlation coefficients (ρ) when testing for the uncorrelatedness between two time series, of which the integrated orders are not able to be equal to each other. We first demonstrate the Pearson's ρ and its resulting Lagrangian multiplier (LM) correlation test of Breusch and Pagan (1980) stay inconsistency as the integrated orders of two time series are different and then suggest to reconstructing this ρ by the AR-filtering residuals fitting from two integrated order-imbalanced time series. We further propose two easy-to-implement correlation tests for checking whether two different integrated order processes are uncorrelated via AR approximations, namely, the extension of Hong (1996) statistics to two order-imbalanced time series and the AR approximation version of LM test. Our simulations not only show the inconsistency of the conventional Pearson ρ for two time

¹We also appreciate the helpful comments of the conference and seminar participants at the 2015 World Congress of Econometrics Society.

series displaying different integrated orders, in contrast to the traditional comprehension of ρ , but also illustrate, in finite samples, the significant improvement of the newly built Pearson's ρ as well as the convincing size and promising power performances of the new proposed LM and Hong correlation tests . More importantly, our new method can overcome the issue of spurious and imbalanced regression analyzed in literature. Finally, to validate the usefulness of our method, we present empirical support not only on resolving the risk-return puzzle in intertemporal capital asset pricing (ICAPM) theory, that postulates the negative and the linear relation between the expected return and conditional variance, but also on proposing a leading indicator to detect the potential crises and their corresponding consequences.

Does the Identity of Leaders Matter for Education? Evidence from the First Black Governor in the US

Mery Ferrando

FNRS and Université catholique de Louvain, CORE

e-mail: mery.ferrando@uclouvain.be

Véronique Gille

IRD, UMR DIAL, PSL, Université Paris-Dauphine

e-mail: gille@dial.prd.fr

Discipline: Economics and Game Theory

Keywords: education, minority, political leaders, aspirations

JEL Classification: I24, D01, O51

This paper analyzes whether political leaders from disadvantaged minorities improve educational outcomes of teenagers and young adults from the same minority. Specifically, we analyze the impact of the first African American governor ever elected in the United States, Douglas Wilder, who became governor of the State of Virginia in 1990. Using individual level survey data, we study how the educational achievements of black teenagers from Virginia evolved after the election of Douglas Wilder and we study the channels for the effect. The empirical specification follows a double and triple-difference strategy, using whites and other states as controls. The results show that, following the election, there was a significant and sizeable increase in the probability of getting a high school diploma for black teenagers in Virginia compared to whites. Our findings suggest that policy changes alone cannot explain this increase and we find evidence that the aspirations of black students improved. This indicates that Douglas Wilder may have acted as a role model for black teenagers in Virginia.

Fertility and Labor Supply: New Evidence Using Time-to-Conception

Claudia Hupkau

Centre for Economic Performance, London School of Economics

e-mail: c.hupkau@lse.ac.uk

Marion Leturcq

INED (French Institute for Demographic Studies)

e-mail: marion.leturcq@ined.fr

Discipline: Economics and Game Theory

Keywords: Labor force supply of women, infertility shocks, time-to-conception

JEL J13, J21, J22

We analyse the impact of children on their mothers' labor market outcomes in the UK. We use time-to-conception of the first child as an exogenous variation in the probability of having a second child. We find that the impact of an additional child on labor force supply of high- and intermediate-skilled mothers is not significant whereas it is large and negative for low-skilled women in the long-run. We show that the selection into having a second child goes in different directions for low-skilled mothers as compared to high-skilled women. Women most attached to the labor market are also those that tend to have only one child among high- and intermediate-skilled women. The reverse is true for low-skilled women: women least attached to the labor market are also less likely to have a second child because they are more likely to break up from their partner.

Sex-selective Abortion: Measuring the Who, How Many & How Often

Aditi Dimri

CORE, Université catholique de Louvain, and Paris School of Economics
e-mail: aditi.dimri@student.uclouvain.be

Véronique Gille

IRD, UMR DIAL, PSL, Université Paris-Dauphine
e-mail: gille@dial.prd.fr

Philipp Ketz

Paris School of Economics
e-mail: philipp.ketz@psemail.eu

Discipline: Economics and Game Theory

Keywords: Sex-ratio, sex-selective abortion, measurement, India

JEL Classification: D1, K13, 015

Any imbalance in the aggregate sex ratio at birth provides an estimate of the total number of sex-selective abortions. With increasing imbalance seen in some countries, unknowns about the extent and nature of sex-selective abortions, which is an illegal procedure, is a glaring issue.

In this paper, we provide a methodology to estimate, using household level data, the fractions of populations undergoing sex-selective abortions and the number of repeated abortions. Our methodology uses the increase in time between two births resulting from abortion. Using maximum likelihood, we estimate a simple structural model of the joint probability of the birth being of a particular gender and the birth happening after a certain number of months given the gender of the birth.

We use three rounds of DHS India datasets to estimate the extent of sex-selective abortions over time and across subgroups of the population.

Revealed Preference Tests of Collective Models of Consumption Behavior

Fabrice Talla Nobibon FedEx	Laurens Cherchye KU Leuven	Yves Crama Université de Liège
Thomas Demuyneck Maastricht University	Bram De Rock Université Libre de Bruxelles	
Bart Smeulders KU Leuven	Frits C.R. Spijksma KU Leuven	

Discipline: Economics and Game Theory

Keywords: Revealed Preference, Operations Research

The word ‘economics’ stems from the Greek ‘oikos nomein’, which is literally translated as ‘running the household’. Households form the cornerstone of our society and, as a result, household consumption decisions drive a huge part of our economy. It is by now well established that the unitary model, which assumes that households behave as single decision makers, is not adequate to describe the behavior of households with multiple members. Therefore, as a more useful alternative, the collective model of household consumption has been suggested in literature. This model explicitly recognizes that households consist of multiple individuals (or decision makers) with their own (rational) preferences.

To verify the empirical adequacy of a particular consumption model, it is important to come up with reliable tests that can be applied to household consumption data. These tests check whether the observed household behavior is consistent with the model predictions; such consistent behavior is then commonly referred to as *rational* in terms of the model subject to testing. Preferably, rationality tests avoid all types of ad-hoc choices. Rather than describing a model’s testable restrictions on observed household behavior in terms of derivatives of certain unobservable functions (e.g., symmetry of the cross-derivatives of the consumer’s cost function), the revealed preference approach defines testable implications in terms of finite systems of inequalities that only involve the household consumption choices

that are actually observed (and summarized in terms of prices and quantities). As such, the approach effectively minimizes the risk of specification error. It avoids that the collective model is rejected simply because of a wrongly specified functional structure (rather than a bad empirical fit of the model per se).

We describe the following results. First, we develop exact algorithms based on a mixed-integer programming (MIP) formulation of the revealed preference tests. Second, we settle the computational complexity of a number of revealed preference tests for the collective model. Finally, we describe a simulated annealing heuristic that can be used for deciding the rationality of large datasets.

Strategic Philanthropy

Vicky Barham & Roland Pongou
University of Ottawa, Department of Economics
e-mail: vbarham@uottawa.ca; rpongou@uottawa.ca

Discipline: Economics and Game Theory

Keywords: public goods; strategic philanthropy

JEL Classification: H40, H41, H49

We propose a theoretical model of strategic philanthropy. We study the private provision of horizontally differentiated public goods in an environment in which donations to the public good influence both the amount of the good produced, and the specific quality of the good, e.g., the number of hours of radio broadcasts, and whether the station plays classical music, jazz or hip-hop. We focus largely on economies in which potential donors differ only with respect to the preferred location of the public good. In the case of a single public good, we show that the level of provision increases as agents' tastes become more dispersed, and donors with more extreme tastes contribute more. In the more interesting setting where there are multiple public goods, we show that there are equilibria consistent with both traditional philanthropy, in which donors typically make smaller contributions to several public goods, and with strategic philanthropy, in which donors concentrate their giving on a single public good, or a smaller number of public goods. The total level of provision of public goods is higher in the traditional philanthropy equilibrium, but the strategic philanthropy equilibrium is Pareto-superior. In equilibrium, the set of contributors is discontinuous: individuals whose preferred location of the public good is closest to the equilibrium location are the least likely to contribute towards financing its provision.

The Role and Design of Social Long Term Care Insurance When Informal Care Is Uncertain

Chiara Canta
NHH, Bergen, Norway
e-mail: chiara.cant@nhh.no

Helmuth Cremer
Toulouse School of Economics

Firouz Gahvari
Dept. of Economics, University of Illinois at UC

Discipline: Economics and Game Theory

Keywords: Long term care, uncertain altruism, private insurance, public insurance, topping up, opting out

JEL Classification: H2, H5

Long-term care (LTC) is the provision of services to mostly elderly people, who have limited ability to perform basic daily activities. Because of population aging the demand for these service is likely to increase dramatically. Currently a large part of LTC is provided informally by family members, but family solidarity is likely to decrease. The reasons are demographic (childless families), societal (declining family norms), and economic (increasing women labor participation). The possibility of solidarity default requires people to take appropriate steps such as purchasing private insurance, self-insuring, and relying on public insurance.

We study the role of private and public insurance programs in a world in which family assistance is uncertain. We model the behavior and welfare of one generation of “parents” over their life cycle. When young, they work, consume, and save for their retirement. In retirement, they face a probability of becoming dependent. In case of dependence, parents face yet another uncertainty which pertains to the level of informal care they can expect from their children. This is determined by a parameter which represents the children’s degree of altruism or equivalently (the inverse of) their cost of providing care. This variable is randomly distributed over some interval and not known to parents when they make their savings and insurance decisions.

We consider the public provision of LTC both under “a topping up” (TU) and an “opting out” (OO) regime. In the former regime, public insurance can be combined with informal or market care, in the latter public provision of care is exclusive. The effectiveness of both policies is limited by the crowding out of informal care they induce. With TU , crowding out occurs both at the intensive and the extensive margins (level of care and share of children who provide care). With OO there is no crowding out at the intensive margin, but the one at the extensive margin is exacerbated. We show that with TU , social insurance is equivalent to fair private insurance. Social insurance dominates fair private insurance if and only if OO dominates TU . The comparison then crucially depends on the distribution of the altruism parameter.

Finally, we consider a policy combining financial aid on a TU basis with public OO care provision. We show that social insurance is desirable as long as the optimal policy involves the provision of some OO care.

The Rate of Return Allowance

Robin Boadway

Queen's University, Economics Department

e-mail: boadwayr@econ.queensu.ca

Kevin Spiritus

KU Leuven, Onderzoeksgroep Economie en Overheid

e-mail: kevin.spiritus@kuleuven.be

Discipline: Economics and Game Theory

Keywords: Optimal Capital Taxation, Rate of Return Allowance, Excess Returns to Savings

JEL Classification: H21, H24, H26

We study the optimality of taxing capital income according to a Rate-of-Return Allowance (RRA) system as proposed by the Mirrlees Review (2011). In this system, risk-free returns on all assets are tax-exempt, while excess returns of risky assets face a positive tax rate. We adopt a setting in which capital income would be tax-exempt if all assets were risk-free and earned competitive returns. We show that when risky assets with excess returns are made available, the RRA system is generally optimal: risk-free returns are tax-exempt while excess returns face a positive tax rate.

Well-Being Poverty and Labor Income Taxation: Theory and Application to Europe and the US

François Maniquet

Université catholique de Louvain, CORE
e-mail: francois.maniquet@uclouvain.be

Dirk Neumann

Université catholique de Louvain, CORE

Discipline: Economics and Game Theory

Keywords: Well-being, Poverty, Labor Income Taxation

JEL Classification: D63, H21, I32

We study a model in which agents differ in their productive skills and their preferences over labor time/consumption bundles. We assume there is a poverty line, that is, there is a minimal level of consumption below which society finds it unacceptable to let people live. To avoid conflict with individual well-being, we capture the anti-poverty project by requiring redistribution to take place between agents on both sides of the poverty line *provided they have the same labor time*. We combine this requirement with efficiency and robustness requirements to derive social preferences. Maximizing these preferences under incentive compatibility constraints yields the following evaluation criterion: labor income tax schemes should minimize the labor time required to reach the poverty line. We apply this criterion to tax schemes of European countries and the US.

Win-Win Capacity Allocation Contracts in Co-Production and Co-Distribution Alliances

Guillaume Roels

UCLA Anderson School of Management, University of California, Los Angeles
e-mail: guillaume.roels@anderson.ucla.edu

Christopher S. Tang

UCLA Anderson School of Management, University of California, Los Angeles

Discipline: Economics and Game Theory

Keywords: Supply chain management, horizontal alliances, newsvendor model, contracting

In some strategic alliances, a firm shares its manufacturing capacity with another, and the latter shares its distribution capacity with the former. Even though such *bidirectional alliances* have become more common, they remain challenging to manage due to the frequent disputes over capacity allocation especially when demand is uncertain. In this paper, we investigate whether there exists a contractual mechanism that can mitigate the extent of these disputes while improving the profits of all participating firms. We consider two types of bidirectional contracts, namely, the *ex-post transfer payment contract* and the *ex-ante capacity reservation contract*. By modeling the capacity allocation and the bidirectional contract design as a noncooperative game between two firms with non-competing product lines, we show that, relative to a situation with no contract, either contract can improve the alliance's total profit in equilibrium. In terms of distribution of the total surplus, we find that capacity reservation contracts always make both firms better off, whereas ex-post transfer payment contracts may make one firm worse off. Hence, capacity reservation contracts are more likely to be implemented in practice in such bidirectional alliances.

Collaboration and Multitasking in Processing Networks: Humans versus Machines

Jan Van Mieghem

Northwestern University, Kellogg School of Management

e-mail: vanmieghem@kellogg.northwestern.edu

Discipline: Operations Research

One of the fundamental questions in operations is to determine the maximal throughput or productivity of a process. Does it matter whether humans or machines execute the various steps in the process? If so, how do we incorporate this difference in our planning and performance evaluation? We propose some answers by discussing two examples: a theoretical analysis and an empirical study.

Supplier Cutting Corners: Can Excessive Competition Compromise Quality?

Aadhaar Chaturvedi

Université de Namur

e-mail: aadhaar.chaturvedi@unamur.be

Discipline: Operations Research

Increasing competition in the supply base allows the buyer to discover ever lower cost supplier. However, higher competition could also reduce the margins of the supplier, to which it can react by cost-cutting measures that compromise on quality and hence increase buyer's risk of product non-performance. In this paper we develop a reverse auction model to investigate this trade-off between purchase price and quality risk and then study the impact of different sourcing strategies on this trade-off.

Non-Parametric Well-being Comparisons

Koen Decancq

University of Antwerp, CORE, and Princeton University

e-mail: koen.decancq@uantwerp.be

Annemie Nys

University of Antwerp

e-mail: annemie.nys@uantwerp.be

Discipline: Economics and Game Theory

Keywords: Interpersonal well-being comparisons, preferences

JEL Classification: D63, D71

In this paper, we study the problem of making interpersonal well-being comparisons in a multidimensional setting where individuals have heterogeneous preferences over the dimensions of their life. We consider a natural and robust criterium for interpersonal comparisons: two individuals can be ranked when their indifference surfaces do not cross. We propose a flexible way of gradually completing the criterium when indifference surfaces cross. In the limit, the complete version of the criterium is consistent with standard well-being measures such as the ray-utility or full-health equivalent income of the individual. To implement the criterium, we develop a new iterative stated choice procedure which provides narrow non-parametric upper and lower bounds on the indifference surfaces in the consumption-health space. A first test of the criterium has been implemented using the QUALTRICS online survey platform with a convenience sample of about 25 Belgian respondents. The test shows reassuring results in terms of power of the criterium.

A Fairness Justification of Utilitarianism

P.G. Piacquadio

University of Oslo, Department of Economics

e-mail: p.g.piacquadio@econ.uio.no

Discipline: Economics and Game Theory

Keywords: Utilitarianism, Ordinal Preferences, Fairness, Opportunities

Differences in preferences are important to explain variation in individuals' behavior. There is however no consensus on how to take these differences into account when evaluating policies. While prominent in the economic literature, the standard utilitarian criterion faces two major difficulties. First, it requires cardinal measurability and unit comparability of individuals' utilities, which cannot be inferred from individuals' observed behavior. Second, it is normatively controversial as it might support unfair policies. In this paper, we propose an alternative criterion, named *opportunity-equivalent utilitarian*, that overcomes these difficulties. First, our criterion ranks social alternatives on the basis of individuals' ordinal preferences, which can be estimated from individuals' observed behavior. Second, our criterion avoids the conventional critiques to utilitarianism by satisfying the following three fairness axioms: *possibility of trade-offs* sets a limit to the influence any individual can exert on the social ranking; *non discrimination* means that no individual is considered to be more deserving than any other; *equal-preference transfer* requires society to value positively a multicommodity progressive transfer among individuals with the same preferences. We show that, together with *efficiency*, *continuity*, and *separability*, these axioms force the welfare criterion to be the sum of specific indices of well-being that are cardinally measurable, interpersonally comparable, and represent each individual's preferences.

Co-Authorship and the Measurement of Individual Productivity

Karol Flores-Szwagrzak
University of Southern Denmark
e-mail: karolszw@sam.sdu.dk

Rafael Treibich
University of Southern Denmark
e-mail: rtr@sam.sdu.dk

Discipline: Economics and Game Theory

In economics, as well as in other fields, authorship is listed alphabetically. A researcher's contribution to a publication is thus not explicit; it can neither be observed nor verified objectively. Not surprisingly, the existing measures of individual academic productivity either ignore the collaborative nature of research, assigning full authorship to every co-author or attempt to correct for it ad hoc, for example, by dividing a paper's citations equally among its co-authors. We argue that individual authorship, the extent of an individual's contribution to a collaborative paper, can be approximated by systematically observing the varying levels of success of all academic partnerships. We propose a new measure of individual productivity, the co-author score or CoScore, reflecting this inferred authorship. The main idea behind CoScore is that stronger authors usually contribute more than their weaker co-authors and should therefore be given, as a first approximation, a bigger credit for their joint papers. Which researcher is relatively stronger in turn depends on the authorship and worth of all the papers that researcher has contributed to. Our measure, CoScore, naturally captures the relationship between a researcher's contribution to a paper and her individual productivity, as quantified by her score, which is determined endogenously. The worth of each paper is distributed proportionally to each of its co-authors' scores, where the score of an author is defined as the sum of her contributions to all of her papers. Crucially, the scores of all authors are determined endogenously and simultaneously as the solution of a fixed point problem. We show that CoScore is well-defined and that it is uniquely characterized by three properties: consistency, invariance to

merging papers, and invariance to merging scholars. We illustrate CoScore for the two thousand most cited papers in economics.

Fair Intergenerational Decision Making: Ex Ante and Ex Post Approaches

Stéphane Zuber

Paris School of Economics, CNRS

Marc Fleurbaey

Princeton University, Woodrow Wilson School & Center for Human Values

Discipline: Economics and Game Theory

Keywords: Fairness, Intergenerational Equity, Uncertainty, Population Ethics, Social Discount Rate

JEL Classification: D63, D81, H43, Q56

Most analyses of climate policy rely on the discounted utilitarian criterion. The paper develops a set of alternative methods for policy evaluation, named fair ex ante and fair ex post approaches, that carefully disentangle risk aversion and inequality aversion. Following the fair social choice approach, wellbeing measures are expressed in terms of the resources (income, environmental goods, health) available to individuals, rather than ‘utility’. The ex ante approaches insist on satisfying the Pareto principle, at the cost of abandoning social rationality as expressed by a statewise dominance principle. The ex post approaches do satisfy social rationality (embodied in the expected utility framework), but to do so they can only satisfy restricted versions of the Pareto principle. All the criteria are explicit about how welfare is measured (namely through consumption equivalent measures) and they can deal with uncertainty about future preferences. Doing so, we further develop the fair social choice approach to deal with variable population and uncertainty about future preferences.

The paper then studies how preference change and preference uncertainty affect the social discount rate, and contrast the fair and utilitarian approaches in that respect. The social discount rate is a important parameter of intertemporal cost-benefit analysis, and plays a key role for climate policy design (Stern, 2006; Nordhaus, 2007; Weitzman, 2007). Although

the impact of uncertainty about future growth on the social discount rate has been widely discussed, uncertainty about future generations preferences has not been studied yet. Two kind of preferences would matter: risk preferences that determine how much future generations are affected by the risk on their consumption; preferences for environmental quality that determine how non-market impacts are valued compared to market impacts. We show that changes in risk preferences, and uncertainty about these preferences, strongly affect the standard utilitarian approach but not so much the fair ex ante and ex post approaches. This is true both for the economic and the ecological discount rates. The key driver seems to be that risk preferences determine the marginal utility of consumption in the utilitarian approach but not in the fair ones, in which social attitudes towards redistribution are determined by the social observer.

Contract Contingency in Vertically Related Markets

Emanuele Bacchiega

Alma Mater Studiorum - Università di Bologna, Department of Economics

e-mail: emanuele.bacchiega@unibo.it

Olivier Bonroy

INRA and Université Grenoble Alpes, UMR 1215 GAEL

e-mail: olivier.bonroy@grenoble.inra.fr

Emmanuel Petrakis

University of Crete, Department of Economics

e-mail: petrakis@uoc.gr

Discipline: Economics and Game Theory

Keywords: Vertical relationships, exclusive vs. non-exclusive relationships, contract contingency, two-part tariff, product differentiation

JEL D43, L13, L14

In this paper we analyze the optimal behavior of an upstream monopolist producing an input that is necessary to two downstream firms, which use it to produce variants of a vertically differentiated good. The upstream producer may enter an exclusive relationship with one downstream firm only or sign non-exclusive contracts with both, in which case it may decide whether to offer contingent or non-contingent contracts. Contingent contracts may contain terms that are finalized, within bargaining pair, in the (out-of-equilibrium) occurrence that the negotiation in the other pair irreversibly breaks down. Non-contingent contracts cannot contain such clauses. Once decided on the contract type, the actual contractual terms are set by secret but interim observable negotiations between the upstream and downstream firm(s) through the generalized Nash bargaining solution. We show that, under downstream price competition, when the upstream firm has a “high” bargaining weight it prefers an exclusive contract with the high-quality producer, in order to avoid profit dissipating downstream competition. By contrast, for lower bargaining weights, it selects non-exclusive contracts to have outside options in the negotiations. In this case, for “intermediate” bargaining power it prefers contingent contracts,

while for “low” bargaining power it prefers non-contingent contracts. Under downstream quantity competition the upstream monopolist still selects the exclusive contract with the high-quality producer when it has a “high” bargaining power but only offers non-exclusive, contingent contracts when it has a “low” bargaining power. The results on contract contingency/non-contingency are driven by the so-called “commitment effect” whereby, under secret, non-exclusive, interim observable, contracting the equilibrium unit input price is different from the input marginal cost of production. This influences *both* the equilibrium *and* out-of equilibrium payoffs of the monopolist and determines the results. We show that all our results are robust under other forms of product differentiation.

Vertical Integration and Consumer Welfare under Non-Price Competition in the Movie Theater Industry

Vladyslav Nora
Nazarbayev University Department of Economics
e-mail: vladyslav.nora@nu.edu.kz
In Kyung Kim
Nazarbayev University Department of Economics
e-mail: in.kim@nu.edu.kz

Discipline: Economics and Game Theory

Keywords: Vertical Integration, Foreclosure, Movie Theater Industry

JEL Classification: L42, L44, L82

We examine the effects of vertical integration between distribution and exhibition in the movie theater industry. We study a model in which theaters are competing with seat allocations under fixed admission prices and capacity constraints. We demonstrate that vertical integration might distort the market-wide seat allocation and decrease the consumer welfare. Using the rich Korean movie theater data set, we show that as predicted by the model, independently distributed movies are played less than movies of the same quality that are distributed by vertically integrated firms. Also, as the movie quality grows this gap increases. Further, using the variation in the share of vertically integrated theaters across markets and years, we investigate how the vertical integration affects the consumer welfare.

Marshall without Calculus

Luca Panaccione

University of Rome Tor Vergata Department of Economics and Finance

e-mail: luca.panaccione@uniroma2.it

Discipline: Economics and Game Theory

In this paper, we review some classical results concerning the efficiency of competitive equilibria in a partial equilibrium setting. However, differently from the traditional Marshallian approach, we do not employ any first order characterization of agents' choices. Our approach allows to disentangle issues that pertain to efficiency from those that (implicitly) pertain to existence of equilibria, similarly to what is customary in analyses of competitive equilibria in a general equilibrium setting (see, e.g., Mas-Colell et al. 1995, chapters 16 and 17). Furthermore, it provides a smoother transition from the analysis of consumers' and producer choices to the analysis of market interactions in the Walrasian tradition. Finally, it allows a straightforward discussion of the relation between price taking behavior, linear pricing schemes, and surplus generation and extraction. We consider a framework with a finite number consumers and firms who select feasible bundles of consumption good and numeraire good to maximize a quasilinear objective function (utility for consumers and profits for firms). In the first part of the paper, we assume that both consumers and firms are price takers; as a warm-up, the law of demand and the law of supply are proved without making any reference to either marginal utility or marginal cost. Subsequently, we show that price taking within a linear pricing scheme, in short linear pricing taking, is an effective way to generate maximal surplus. To this end, we review the well known result on the efficiency of partial competitive equilibrium. In the second part of the paper, we argue that price making within a linear pricing scheme, in short linear pricing making, is not an efficient way to extract surplus from consumers. To this end, we review the classical inefficiency results associated to excise taxes and monopoly pricing. To conclude the analysis, we compare the

outcome of monopolistic linear pricing with the outcome monopolistic two-part tariff, and we argue that in the second case no deadweight loss occurs since the number of independent instruments (price and fixed fees) matches the number of targets for surplus generation and surplus extraction.

The Role of Capacity Building on Technology Adoption Under Imperfect Competition

Baris Vardar

Université catholique de Louvain, CORE
Université Paris 1 Panthéon-Sorbonne, CES

Thomas Fagart

Université Paris 1 Panthéon-Sorbonne, CES

Discipline: Economics and Game Theory

Keywords: Capacity Choice, Technology Adoption, Financial Constraint, Market Structure, Symmetric and Asymmetric Equilibria

JEL Classification: L11, L13, D43, D24, D92

This work studies the investment choice of firms in a two-period model when there are two different productive capacities that embody two different types of technology. One of them is more efficient (allowing to produce at a lower marginal cost), but more expensive to purchase. Firms face a financial constraint which limits their first period growth. By investing in the capacity using inefficient technology, firms grow faster but face a higher production cost in both periods. The equilibrium behavior is then to invest in a mixture of both types of capacity. This stands in contrast with the literature on technology adoption. Furthermore, under duopoly competition, there exists a symmetric equilibrium and two asymmetric equilibria with preemption, in which one of the firms overinvests in the inefficient capacity to gain a size advantage, whereas its opponent concentrates on efficient capacity. Finally, we find a counter-intuitive policy result: an increase in the purchasing price of inefficient capacity may increase its use.

Necessary Conditions for Infinite Horizon Optimal Control Problems Revisited

Anton O. Belyakov

Moscow school of economics and Institute of mechanics,
Lomonosov Moscow State University

e-mails: belyakov@mse-msu.ru belyakov@imec.msu.ru

Discipline: Economics and Game Theory

Keywords: Ramsey problem, maximum principle, transversality conditions

Optimal control problems with infinite horizon play an important role in economic theory. For instance, in the theory of economic growth, Pontragin's maximum principle is the workhorse for many researchers. The proof of the maximum principle for infinite time horizon (see e.g., Halkin, 1974) does not include transversality conditions. Moreover it is known (Halkin, 1974; Kamihigashi, 2001) that the following usually used forms of transversality conditions can be not necessary:

$$\lim_{t \rightarrow \infty} \psi(t) = 0, \quad \text{or} \quad \lim_{t \rightarrow \infty} \langle \hat{x}(t), \psi(t) \rangle = 0, \quad (1)$$

where \hat{x} is the optimal state trajectory, ψ is the corresponding adjoint variable, and brackets $\langle \cdot, \cdot \rangle$ denote scalar product of two vectors. Transversality condition obtained in Michel (1982) under assumptions including that the objective functional takes only finite values, has the form of Hamiltonian \mathcal{H} converging to zero

$$\lim_{t \rightarrow \infty} \mathcal{H}(\hat{x}(t), \hat{u}(t), t, \psi(t)) = 0, \quad (2)$$

where \hat{x} and \hat{u} are the optimal state trajectory and control. In works by Aseev, Besov, Kryazhimskii, and Veliov (2007-2014) the authors determine the adjoint variable uniquely by a Cauchy-type formula, which is equivalent to the adjoint equation with the following transversality condition:

$$\lim_{t \rightarrow \infty} Y(t) \psi(t) = 0, \quad (3)$$

where $Y(t)$ is the fundamental matrix of the state equation linearized about the optimal solution, see also Khlopin (2015).

All aforementioned transversality conditions fail to select the optimal solution of Ramsey problem without discounting, where we consider diverging objective functional. It can be done with the necessary conditions obtained in the present paper (arxiv.org/abs/1512.01206). The proposed conditions do not contain explicitly the adjoint variable and include condition (3) as a special case, extending its domain of applicability.

On the Uniqueness of Solution to Spatial Dynamic Problems

Carmen Camacho
Paris School of Economics and CNRS
e-mail: Maria.Camacho-Perez@univ-paris1.fr
Agustín Pérez-Barahona
INRA and École Polytechnique
e-mail: agperez@grignon.inra.fr

Discipline: Economics and Game Theory

Keywords: Spatial Dynamics, Land Use, Ramsey Model, PDE

JEL Classification: C62, Q56, O4, R11

Dynamic spatial theory has been a fruitful approach to understand economic phenomena involving space and time dimensions. However, in this new field, the application of partial differential equations (PDE) has opened a set of questions still not solved by the mathematical literature. In particular, the existence of unique solution has not been proven in general, leaving the problem ill-posed. We identify in this paper the Pontryagin conditions for a general spatial Ramsey-type model. These conditions, which are necessary and sufficient, set up a system of non-linear parabolic PDEs that includes reversed-time PDEs as well. By means of a monotone method, we prove the existence of unique solution for this type of problems. Moreover, the iterative nature of this procedure allows us to present a new algorithm to simulate the optimal trajectory of our economy. We finally consider two examples of this type economic models in order to illustrate the applicability of our technique: the spatial Ramsey model itself and the land use dynamics model of Camacho and Pérez-Barahona (2015).

Incentive-compatible debt restructuring

A. de Crombrugghe

Université de Namur, Département des Sciences Economiques

e-mail: alain.decrombrugghe@unamur.be

Discipline: Economics and Game Theory

Keywords: Debt, moral hazard, bargaining

JEL: D82, F34

This paper intends to make sense of observed bank and government debt restructuring programs. Banks and Governments typically back high revolving debts with expected future income from a portfolio of activities whose actual income generation potential depends both upon exogenous macroeconomic circumstances and upon their skills in monitoring and managing the underlying portfolio.

The paper thus considers a two-period model (three dates) with risk-neutral agents. The borrower's management activity is costly and non-observable but generates a higher net expected value from the portfolio at the end of the second period than a management by outsiders. The initial loan is a standard debt contract on a competitive market for funds with limited liability, and with fixed capital and interest payments. In this setup, standard moral hazard results obtain due to the incentive-compatibility constraint: marginally profitable borrowers cannot be debt-financed and the borrower earns an information rent in equilibrium.

Debt renegotiation rests on two further assumptions related to the passage of time: a liquidity need at the end of the first period and the simultaneous revelation of new information either about the borrower's management ability or about the macroeconomic environment. This information may lower the portfolio's expected income below the incentive-compatibility threshold for the contractual debt and for refinancing at the market interest rate. For some range of shocks, the paper shows that it is in both parties' interest to renegotiate the whole debt that is affected by the incentive-compatibility problem. Debt renegotiation may require some centralization

of the claims and the intervention of a resolution agent. Moreover the paper shows that the bargaining position of this agent can be strengthened by a threat to take over the portfolio (or to impose a structural adjustment program in the case of a country). This especially applies when the second-period shock is defined as a deterioration of the borrower's expected management ability.

In this inter-temporal reasoning, the expectation of the intervention of a resolution agent can make standard loans cheaper for borrowers if such arrangements can be expected than if such arrangements are excluded. Debt restructuring is thus a key element of debt management also in the case of borrowers whose operations cannot be dismantled by usual bankruptcy procedures. Specific skills and moral hazard concerns actually strengthen the borrower's position as long as outsiders cannot hope to get more by taking control or by imposing policy reforms.

Multidimensional Free-Mobility Equilibrium: Tiebout Revisited

Alexey Savvatee

New Economic School CSDSI, Moscow Institute of Physics and Technology,
Laboratory of Social Analysis at the Russian Endowment for Science and Education

e-mail: hibiny@mail.ru

Constantine Sorokin

NRU Higher School of Economics, New Economic School CSDSI

e-mail: csorokin@hse.ru

Shlomo Weber

Southern Methodist University, New Economic School CSDSI

e-mail: sweber@mail.smu.edu

Discipline: Economics and Game Theory

Keywords: Tiebout Sorting, Local Public Goods, General Equilibrium, Group Formation, Social Interactions

JEL Classification: D71, H20, H73

The paper provides consistent mathematical framework for seminal Tiebout free-mobility model (1956). Our setting supports continuum of consumers with multidimensional preferences and finite number of strategic public good providers. We accommodate the most general assumptions: providers' production function may have variable returns to scale, our framework is rich enough to incorporate possible externalities, spillovers, scale economies, network effects, etc.; consumers utility may depend on choice of other agents in almost arbitrary way. We focus on equilibrium existence, however the questions of efficiency and stability are not left behind.

Whither Social Choice?

Marc Fleurbaey
Princeton University
e-mail: mfleurba@princeton.edu

Discipline: Economics and Game Theory

Five problems have been bothering social choice theorists and still cast a shadow on applied welfare economics and cost-benefit analysis: 1) Arrow's impossibility; 2) Sen's Liberal Paradox; 3) Harsanyi's utilitarian theorem; 4) Parfit's "repugnant conclusion"; 5) Maximin theorems in fair allocation. These problems reveal deep conceptual issues and point to the need for a map of the tensions between the ethical values that people of good will would like to jointly promote in social and economic policies. In this lecture, I will revisit our understanding of how hard or soft the difficulties are, and argue that we should explore the construction of a normative theory for (past, present and future) humanity as a whole.

Multiple Contracting in Insurance Markets

Andrea Attar

TSE and University of Roma Tor Vergata,

e-mail: andrea.attar@gmail.com

Francois Salanié

TSE

Thomas Mariotti

TSE

Discipline: Economics and Game Theory

We analyze the positive and normative implications of multiple contracting in insurance markets subject to adverse selection. We characterize the set of incentive feasible allocations in this context, and we show that the treaty of multiple contracting dramatically restricts the planner's opportunities to redistribute among different agents' types. At equilibrium, different layers of coverage are fairly priced according to the types of consumers who purchase them, giving rise to cross-subsidies between types, but not between contracts. Riskier consumers demand greater total coverage at an increasing unit price, but the contracts offered by firms exhibit quantity discounts. We emphasize the need to regulate the supply side of insurance markets, while consumers can be left free to choose their coverage level.

Playing the Game the Others Want to Play: Keynes' Beauty Contest Revisited

Rodolphe Dos Santos Ferreira
Université de Strasbourg,
e-mail: rdsf@unistra.fr

Discipline: Economics and Game Theory

In Keynes' beauty contest, agents make choices by referring to their expectations of some fundamental value and of the conventional value to be set by the market. In doing so, agents respond to fundamental and strategic motives, respectively. The prevalence of either motive is usually set exogenously. Our contribution is to consider whether agents favor one of the two motives when the relative weights put on them are taken as strategic variables. We show that the strategic motive tends to prevail over the fundamental one, yielding a disconnection of agents' actions from the fundamental. This is done in a simple valuation game emphasizing the role of public information. We then extend the same result to competition between the owners of two firms, by using a delegation game in which informational issues are embedded into a broader microfounded setting.

The Strategic Use of Seller's Information in First-Price Auction

Todd Kaplan

University of Exeter

Shmuel Zamir

The Hebrew University of Jerusalem, Center for the Study of Rationality

e-mail: shmuelzamir@gmail.com

Discipline: Economics and Game Theory

In the framework of a first-price private-value auction, we study the seller as a player in a game with the buyers in which he has private information about their realized valuations. We ask whether the seller can benefit by using his private information strategically. We find that in fact, depending upon his information, set of signals, and commitment power he may indeed increase his revenue by strategic transmission of his information

Dynamic Bank Runs

Olivier Gossner
CNRS - École Polytechnique
e-mail: ogossner@gmail.com

Discipline: Economics and Game Theory

We examine dynamic models of bank runs with asymmetric information between depositors. Our model admits a unique equilibrium in threshold strategies, and we discuss its comparative statics with regards to player's information and fundamentals of the economy.

The Effectiveness of the R&D Tax Credit at the Extensive Margins in France

Benoit Mulkey

Université de Montpellier, LAMETA

e-mail: benoit.mulkey@umontpellier.fr

Jacques Mairesse

Maastricht University, UNU-MERIT, and CREST-ENSAE

e-mail: jacques.mairesse@ensae.fr

Discipline: Econometrics

Keywords: R&D, Research tax credit, Selectivity model, Panel Data

JEL Classification: C23, C24, H25, H32, O32.

Many countries have introduced a R&D tax credit in order to promote companies' R&D, to increase the innovations, and to raise the firms' productivity. Now the empirical econometric literature agrees to show the effectiveness of the R&D tax credit all over the world either by using matching methods or by estimating structural models.

However many of these studies on firms panel data are limited to the minority of firms doing R&D on several years. Moreover a dynamic model with a few lags necessitates a long period of R&D for firms. Therefore we cannot use in econometric estimation firms which starts (or stops) their R&D activity, because a fairly long period of observations with R&D is needed. In consequence, the effectiveness of R&D tax credit is investigated at the intensive margin.

In this study, we try to assess the effectiveness of R&D tax credit in France at the extensive margin including the firms which begin a R&D project as well as on firms with a continued R&D activity. We derive a selection mechanism with a fixed cost for the decision to undergo R&D, as well as the classical R&D intensity equation with the effect of tax credit on the cost of R&D investment. We can also introduce the effect of R&D direct subsidies.

This model is estimated jointly on a large panel data for France during the period 1999-2013 because France has experienced a large change in the policy supporting the R&D during the decade: from an incremental R&D tax credit up to 2003 to a pure volume R&D tax credit since 2008. In the same time there was a decrease in direct public subsidies to the R&D. The econometric estimation requires the estimation of a joint model for the selection equation (a probit model) and the intensity equation (a linear regression model) with correlated individual random effects in both equations.

The estimations allow us to derive some conclusions on the effectiveness of the change of public policy at the intensive margin and now, at the extensive margin.

Environmental Regulation and Eco-innovation: Insights from Diffusion of Innovations Theory

A. Bitat

Université Saint-Louis Bruxelles,
Faculté des sciences économiques, sociales, politiques et de la communication
e-mail: abdelfeteh.bitat@usaintlouis.be

Discipline: Environmental Economics

Keywords: Porter Hypothesis, Environmental regulation, Environmental innovation, Diffusion of innovations, Count Data.

JEL Classification: C23, H23, O31, O38, Q55.

The paper analyses the relationship between environmental regulation and environmental innovation based on the diffusion of innovations theory. We build the analysis on three theoretical approaches. Firstly, based on the neoclassical approach we compare three policy alternatives: legally binding instruments, financial and market incentives, and self-regulation. Secondly, based on the evolutionary theory we add the interactions between different policy instruments. Thirdly, based on the "induced innovation" approach we account for endogeneity and path dependency. The relationship is tested using a German firm-based panel and a Count Data model. We estimate the propensity of firms to innovate in response to five initiating factors, namely the fulfilment of legal requirements, expectations towards legal requirements, financial incentives, demand for environmental innovations and self-commitment. We also control for R&D intensity, the region and the sector of the company and filter for companies that account for their environmental impact. The results answer the central question concerning the design of environmental policies in order to foster innovation. Comparing a static model to a dynamic one, we show that only performance and market incentives are positively associated with environmental innovation. Conventional regulatory tools, namely technology-based command and control, are not effective for triggering innovative behaviour at

the firm level. Lastly, we show that environmental regulation is a necessary condition for eco-innovation.

Competition and Coalition for Smart Energy Supply¹

H. Le Cadre / N. Bourdin
ENSTA ParisTech, UMA

e-mails: {helene.le-cadre,nicolas.bourdin}@ensta-paristech.fr

Discipline: Operations Research

Keywords: Demand Response, Coalition, Market, Pricing

JEL Classification: C61, C63, C71, C83

The transformation of energy systems is accelerating. The drop of renewable energy costs and the impulse of local agents have encouraged the blossoming of myriads of decentralized sources producing renewable energy (wind, solar photovoltaic power), known as being highly unpredictable.

Energy systems, which were controlled by a central agent, are becoming more and more decentralized with a multiplicity of local agents acting selfishly and having only partial access to information. Decentralized systems can take various forms: hierarchical, team based, coalition based, depending on the economic relations underlying the interactions between the agents in the system.

We consider new entrants in the electricity markets: the aggregators, which manage coalitions of agents i.e., sets of end users who agree on a joint demand profile to be contracted in the wholesale electricity market. The aggregator's task is made of three parts that are nested: 1) scheduling the shiftable loads of its coalition participants, 2) taking forward positions in the day-ahead electricity market to compensate the uncertainty associated with the base load estimation, 3) pricing its supply service so as to reach a targeted profit. Solving these three tasks requires to determine the core of the Transferable Utility (TU) game that takes place between the aggregator and the conventional retailer. The core is the set of allocations of

¹The authors would like to thank P. Carpentier, M. De Lara and J.-P. Chancelier for helpful discussions, and acknowledges the support of PGM0.

the aggregator's revenue that stabilize its coalition such that the coalition participants have no incentives to switch to the conventional retailer. We also consider various fairness criteria to characterize these allocations. The consumers having the possibility to perform demand shedding, we compute the optimal coalition size as a function of game parameters and targeted profit. Simulations are performed on a case study.

Optimal Design and Time Development of New Hydrogen Transmission Pipeline Networks

Daniel DE WOLF

Université du Littoral Côte d'Opale, Département Economie Gestion

e-mail: daniel.dewolf@univ-littoral.fr

Jean ANDRE

Stéphane AURAY

GDF SUEZ,

Ensaï-CREST

R & D Division, Paris, France

Rennes, France

Mohamed-Mahmoud MEMMAH,

INRA, Avignon, France

Antoine SIMONNET,

TOTAL Raffinage et Marketing, Paris, France

Discipline: Operations Research

Keywords: Hydrogen, Energy Economics, Time Scheduling, Network Deployment, Penetration Rates

The development of an hydrogen economy will need a transportation infrastructure to deliver hydrogen from production sites to end users. For the specific case of hydrogen, pipelines networks compete with other hydrogen carriers: compressed gas trucks and liquid cryogenic trucks.

This work considers first the problem of the optimal design of hydrogen transmission networks. The problem includes the topology determination and pipelines dimensioning. We define a local search method that simultaneously looks for the least cost topology of the network and for the optimal diameter of each pipe. These two problems were generally solved separately. The solution procedure is applied to the case of the development of a new hydrogen pipeline network in France. In this study, we also consider the determination of the temporal deployment of a new hydrogen transportation infrastructure. Starting from the expected final horizon pipelines network, we propose a backward heuristic approach.

The proposed approach is illustrated on the national French hydrogen transportation tacking into account two scenarios for hydrogen penetration into the fuel markets : high demand level and low demand level for

hydrogen.

This study shows that the two stage-approach generally used (first look for a minimal length network and then optimizing the diameters) is not efficient. We show that increasing the total length of the network can help to decrease the network cost by using smaller diameters for some pipes. Concerning the optimal time development of the network, we showed that for the mid term perspective and low market share, the trucks are the most economical options. However, for the long term, the pipeline option is considered as a economical viable option as soon as the hydrogen energy market share for the car fueling market reaches 10%.

Remuneration of Flexibility using Operating Reserve Demand Curves: A Case Study of Belgium

Anthony Papavasiliou, Yves Smeers, Mathieu Van Vyve
Université catholique de Louvain, CORE
e-mail: anthony.papavasiliou@uclouvain.be

Discipline: Operations Research

Flexibility is becoming an increasingly important attribute of conventional generators due to the challenges imposed by the unpredictable, highly variable and non-controllable nature of renewable supply. Paradoxically, flexible units are currently being mothballed or retired in Europe due to financial losses. We investigate an energy-only market design, referred to as operating reserve demand curves, that rewards flexibility by adjusting the real-time energy price to a level that reflects the value of capacity under conditions of scarcity. We test the performance of the mechanism by developing a model of the Belgian electricity market, which is validated against the historical outcomes of the market over a study period of 21 months. We verify that (i) based on the observed market outcomes of our study period, all existing combined cycle gas turbines of the Belgian market units cover their operating costs, however none of them fully recover their (sunk) investment costs, and (ii) the introduction of price adders that reflect the true value of scarce flexible capacity are adequate for most combined cycle gas turbines in the Belgian market to recover their fixed investment costs.

Risk Neutral and Risk Averse Approaches to Multistage Stochastic Programming

A. Shapiro

Georgia Institute of Technology, Industrial and Systems Engineering
e-mail: ashapiro@isye.gatech.edu

Discipline: Operations Research

Keywords: Stochastic programming, multistage, distributional robustness, risk measures, time consistency, dynamic programming, SDDP algorithm

AMS Classification: 90C15, 90C47, 91B30

In many practical situations one has to make decisions sequentially based on data available at the time of the decision and facing uncertainty of the future. This leads to optimization problems which can be formulated in a framework of multistage stochastic optimization. In this talk we consider risk neutral and risk averse approaches to multistage stochastic programming. We discuss conceptual and computational issues involved in formulation and solving such problems. As an example we give numerical results based on the Stochastic Dual Dynamic Programming method applied to planning of the Brazilian interconnected power system.

Stochastic Programming Models for Energy Planning

Mario Veiga Pereira
PSR, Rio de Janeiro, Brazil
e-mail: mario@psr-inc.br

Discipline: Operations Research

For several decades, power system planning and operations has been one of the most active application areas for multistage stochastic optimization techniques. This is due to the combination of the following factors: (i) ever increasing social and economic importance of electricity supply for both developed and emerging countries; (ii) yearly investment and operation costs on the order of hundreds of billions of dollars; (iii) coupling of time stages due to storage, originally from hydro reservoirs and, more recently, batteries and other devices; (iv) uncertainties on several key parameters, such as the production variability of hydropower, wind and other renewables; annual demand growth; fuel costs; construction times; macro-weather effects such as El Niño, plus climate change; and short-term electricity prices. In this talk, I will describe some recent algorithmic and modeling advances on one widely applied technique, stochastic dual dynamic programming (SDDP): (a) implicit representation of the immediate cost function in each stage as a pre-calculated piecewise linear surface, which allows the detailed modeling of 730 hourly intervals in each stage with the same computational effort as an aggregate model with five blocks; (b) representation of uncertainties in the parameter values of wind and inflow stochastic models (this problem became relevant due to the shorter historical records of modern renewables); (c) an integrated Markov chain-AR model framework for the joint representation of uncertainties of renewable production, load growth, fuel costs, macro-weather and spot prices; (d) generation expansion planning with a risk-averse SDDP (CVaR on either operating costs or supply reliability); and (e) an extension of SDDP to produce generation expansion strategies, in which the investment decisions depend on the system state, for example

past load growth rates. This allows the correct valuation of technologies with different construction times (e.g. six years for hydro, three for a gas turbine and two for wind) when planning under uncertainty. The application of the above algorithms will be illustrated for actual planning and operation studies in Latin America and Asia.

Large-Scale Optimization in Electric Energy Systems: Dealing with Nonconvexity, Dynamics, and Uncertainty

Andy Sun

Georgia Institute of Technology

H. Milton Stewart School of Industrial & Systems Engineering

e-mail: andy.sun@isye.gatech.edu

Discipline: Operations Research

Keywords: Large-scale optimization, robust optimization, stochastic programming, convex relaxation, electric power systems

In this talk, we will present our recent work on some fundamental optimization problems in electric power systems, including the optimal power flow (OPF) problem, the optimal transmission switching (OTS) problem, the unit commitment (UC) problem, and the generation expansion problem. The first two are notoriously non-convex, and the last two are subject to significant uncertainty and dynamics. In the first part of the talk, we will present strong second-order cone programming (SOCP) relaxations for solving large-scale AC OPF problems and their applications in solving the OTS problem. Extensive computation shows the proposed SOCP relaxations produce very high quality solutions compared to SDP relaxations and are orders of magnitude faster. In the second part of the talk, we will present our recent work on multistage robust and stochastic optimization for the UC and generation expansion problem. For UC, we propose simplified affine control policies and develop efficient constraint generation algorithms that solve real-world power systems of more than 3000 buses in a time framework suitable for today's industry practice. For the generation expansion problem, we propose efficient reformulations and valid inequalities to significantly speed up the convergence of the stochastic dual dynamic programming (SDDP) algorithm on solving multistage stochastic integer programs.

Solving Stochastic Unit Commitment at Industrial Scale through Parallel Computing: A Case Study of Central Western Europe

I. Aravena, A. Papavasiliou
Université catholique de Louvain, CORE

e-mail: ignacio.aravena@uclouvain.be, anthony.papavasiliou@uclouvain.be

Discipline: Operations Research

Keywords: Renewable energy integration, asynchronous algorithms, zonal electricity markets

AMS Classification: 68W15, 46N10

The large-scale integration of renewable energy resources in Europe is causing numerous operational challenges in short-term (day-ahead and real-time) power system operations due to the lack of coordination among European system operators. The present work analyzes the operational cost impact of large-scale renewable energy integration in the European electricity market by comparing the existing European market design to two benchmark models of perfect coordination: stochastic unit commitment, and deterministic unit commitment. We focus on an industrial scale case study of the Central Western European (CWE) system comprising 656 generators, 679 nodes and 1073 lines. The model features multi-area renewable production at a 15 minute time resolution.

We propose an asynchronous dual decomposition algorithm for solving transmission constrained two-stage stochastic unit commitment. The algorithm is motivated by the problem scale and large differences in run time observed among scenario subproblems. The asynchronous algorithm is implemented on a high performance computing cluster. We present results for instances of stochastic unit commitment on the CWE system with up to 120 scenarios that achieve a running time which outperforms a deterministic unit commitment formulation with reserve requirements.

We further analyze the implications of zonal market design on cost efficiency in the CWE region. We find that the inefficiencies of zonal market design and the limited coordination among transmission system operators overwhelmingly exceed the benefits of stochastic unit commitment relative to deterministic unit commitment. We conduct a detailed analysis of the numerical results in order to explain the relative performance of the different models.

A Notion of Statistical Equilibrium for Games with Many Players

Peter J. Hammond
University of Warwick, Department of Economics
e-mail: p.j.hammond@warwick.ac.uk

Discipline: Economics and Game Theory

Keywords: Games with many players, statistical equilibrium, Monte Carlo simulation

JEL Classification: C72, C02, D50, E00

The economist's ideal of a perfectly competitive market involves many participants. Such a market is often described using a game with many players. Similar games arise when economists discuss public finance, mechanism design, insurance, and macromodels of national or international economies. Formally, the player set in a large game has usually been represented by the uniform probability distribution over the Lebesgue unit interval of the real line. Yet this poses significant measurability issues, especially when considering the probability distribution over players' strategy profiles induced by mixed or correlated strategies. This has recently led some mathematical economists to explore greatly enriched player spaces. Here I propose a more workable "statistical" approach that distinguishes between the unit interval of potential players and the countably infinite set of actual players drawn randomly from this interval. Then a suitable Bayesian Nash "statistical" equilibrium in pure strategies exists for a broad class of large games.

Non-Cooperative Equilibrium with Multiple Deviators

Dmitry Levando

National Research University, Higher School of Economics

e-mail: d.levando@hotmail.com

Discipline: Economics and Game Theory

The paper suggests a non-cooperative game, where a number of potential deviators is a fixed parameter and demonstrates an equilibrium existence for the game. A maximum size of a deviating set of players is equal to a value of the parameter and modifies a set of strategies in the game. A central planner offers a menu of possible coalition structures over the set of all strategies in the game. Individual payoffs are defined for every structure analogous to state-contingent payoffs in finance. The constructed game includes intra and inter group externalities for every coalition structure. We construct a non-cooperative stability criterion to describe commitment of the players to an equilibrium for a fixed number of deviators. It may serve as a measure of a trust for an equilibrium.

Common Knowledge in Correlated Equilibria and Global Games

F. A. Pirrone

Université catholique de Louvain, CORE

e-mail: andrea.pirrone@uclouvain.be

Discipline: Economics and Game Theory

Keywords: Correlated Equilibria, Incomplete Information, Common Knowledge, Global Games

JEL Classification: C72, D82, D83

In most economic interactions - e.g. agents investing in the stock market, oligopolistic firms deciding the quantity to supply, etc. - agents do not observe neither the actions, nor the type of the other players. In all these cases the price system is the main communication mechanism, which, aggregating private information and partially revealing it, coordinates economic agents.

This paper formalizes this communication mechanism, showing how agents' coordination arises from the creation of common knowledge.

First, we formalize this indirect form of communication. Correlated equilibria allow for communication among players, usually through the presence of a mediator. Here, we introduce a specific communication device, allowing agents to use it before playing. We design a communication device which takes the possible strategy of each player as an input, returning a public signal (whose value depends on the inputs) as an output. After observing it, each agent has to decide whether to communicate again or to implement the strategy communicated. The public signal creates common knowledge, coordinating players' decisions, and constraining the support of the correlation device.

Then, we illustrate how players may reason about their opponents. The constraint introduced on the communication device (stochastic monotonicity) is necessary to define an equilibrium where all the players agree about opponents' strategies and therefore maximize their expected utility. This

also guarantees the existence of the equilibria defined. We find that the epistemic conditions sufficient for an equilibrium do not require neither mutual knowledge of rationality, nor common knowledge of overall conjectures.

We also show how the equilibria defined are equivalent to the ones derived from a learning process, where agents act, observe the public signal, refine their information, act again and so on. This differs from the initial setup, because communication is not allowed in a pre-phase of the game.

Finally, we focus on the economic relevance of our modeling approach. To illustrate this point, we remark a difference with respect to global games. In these models agents receive independent noisy private and public signals about a payoff relevant random variable. When the private signal is relatively more precise than the public one, agents' coordination becomes unlikely, leading to the selection of a unique outcome. On the other hand, dropping signals' independence restores coordination and multiplicity. In our setting the selection of a unique outcome is still possible, since not only beliefs update but also their support changes.

The Missing Link: Leveraging Consumers' Recycling Incentives in a Circular Economy

V. Forlin

Université catholique de Louvain, CORE
e-mail: valeria.forlin@uclouvain.be

E. Scholz

Université catholique de Louvain, CORE

Discipline: Economics and Game Theory

Keywords: circular economy, extended producer responsibility, take-back programs

JEL Classification: L13, Q53

Several brands, notably in the fashion or consumer electronics industries, recently introduced take-back programs (TBPs), which consist in offering consumers a reward if they drop off their past purchase at a collection point. TBPs are a strategy in line with the circular economy paradigm, since they allow firms to re-use or re-sell their products or some components of them at the end of the products' lifetime.

In order to analyze firms' incentives to introduce TBPs, we build a two-period Hotelling duopoly in which consumers are vertically differentiated according to their environmental preferences. We identify three main drivers of firms' decisions: (i) Firms want to increase consumers' opportunity costs of purchasing from a competitor without a TBP: from this point of view, a TBP policy is a marketing tool to attract consumers with environmental preferences; (ii) Firms try to better comply with Extended Producer Responsibility policies, modelled here as taxes on the share of old production that is not recollected at the point of sale (take-back targets); (iii) Firms make net benefits from the re-use / re-selling of recycled units, which have an intrinsic value.

Depending on the relative strength of these three effects, TBPs have different implications in terms of industry prices and profits. In particular, the value of the net benefits from recycled units is crucial in determining

the uptake of TBP initiatives: for low values of recycling benefits, no firm adopts a TBP, while for large values, both firms do (symmetric equilibrium). For intermediate recycling benefits an asymmetric equilibrium may arise in which only one firm adopts a TBP.

A welfare analysis shows that the symmetric equilibrium is in most cases surplus-minimizing for firms, but surplus-maximizing for consumers; moreover, it is evidently the best scenario in terms of environmental outcomes (that is, it implies the largest volume of recycled units). In this context, we also show that introducing a stricter EPR policy can decrease the threshold of recycling benefits above which the symmetric equilibrium arises, thus making this outcome more likely.

Therefore, a policy implication of our model is that stricter Extended Producer Responsibility policies, and the consequently larger uptake of TBPs, are beneficial for consumers and the environment, but less so for producers.

Environmental Taxation and Heterogeneous Firms Selection

Nicolas Gonne

Université de Namur, Department of Economics
nicolas.gonne@unamur.be

Discipline: Economics and game theory

Keywords: Environmental taxation, heterogeneous firms selection, intraindustry reallocations, welfare

JEL Classification: H23, H32, L11, Q58

I develop a closed-economy version of Melitz's (2003) monopolistic competition model with heterogeneous firms, which I augment with a Copeland and Taylor (1994) production technology. In that model I study the impact of a pollution tax on industry aggregates and show how firm-level economic behaviours aggregate to produce that pattern.

From a positive standpoint I show that (an increase in) the tax levy entails winners and losers, for it generates intraindustry reallocations which affect firms according to their idiosyncratic productivity level. Following a tax hike indeed, firms with a relatively low productivity level exit the market, firms with intermediate productivity contract and very productive firms expand. In other words, environmental taxation magnifies the impact of firm-level heterogeneity on the industry equilibrium. The mechanism I highlight here is grounded in the optimization of the cost structure: all firms experience an increase in production costs following the tax increase, but more productive ones are better able to substitute labour for pollution, hence survive and capture the market shares previously held by the ones which left the industry.

I further show how the proportion of firms which benefit from the environmental policy depends on market distortions, namely market power and the entry process. Interestingly the relative measure of winners and losers turns out to depend on estimable structural parameters, opening the

way to empirical work aimed at validating the theoretical predictions of the model.

Next I take a normative stance and study the level of the environmental tax which a welfare-maximizing government should levy when pollution imposes external diseconomies. I show that the optimal tax need not be too high in an industry characterized by a high degree of heterogeneity, for it entails a more concentrated market made up of more productive, hence less polluting firms. I also point out that the market structure affects the optimal tax level in two opposite directions. On one hand a high substitution elasticity attenuates underproduction, hence the government ought to correct heavily for the externality. On the other, it makes the market more competitive, implying that the marginal firm is less polluting and requires a lower tax level. The first effect dominates for low values of the substitution elasticity, while the second does for high values.

Assessing the Impact of Environmental Taxation on Green Technology Competition

Anna Creti

Université Dauphine and Ecole Polytechnique, France.

Maria-Eugenia Sanin

EPEE, Université d'Evry Val d'Essonne and Ecole Polytechnique, France.

Till Requate

Kiel University, Germany.

Discipline: Economics and Game Theory

Keywords: Environmental Tax, Green Technology, Competition

JEL Classification: L5, Q2, Q28

One of the main arguments justifying environmental regulation is that it provides incentives to adopt more efficient abatement technologies. In this paper we compare different commitment tax schemes in terms of adoption and efficiency when accounting for a non-competitive sector that offers two green technologies with differentiated value both in terms of quality and adaptability to polluting firms. Our modelling choice is inspired by the Californian Green Chemistry Initiative and responds to the need to analyze the role of environmental regulation in complex green technology market structures. In this context we find that, in line with Requate (2005) but in contrast with Parry (1995), the ex ante second best tax must be higher than the marginal damage caused by emissions. Additionally, we show how the regulator's choice regarding commitment influences the strategies of green technology firms, which in turn determines the adoption pattern each of the competing technologies and consequently on efficiency and emissions.

Natural Resource and Growth in a Federation

Robin Boadway
Queen's University

Motohiro Sato
Hitotsubashi University

Jean-François Tremblay
University of Ottawa

Discipline: Economics and Game Theory

In this paper, we analyze a natural resource extraction problem in a two-region economy with mobile labour. One of the regions produces only manufacturing goods while the other produces services and extracts a non-renewable natural resource. The manufacturing sector exhibits increasing returns-to-scale if the level of production is sufficiently high. The analysis shows that there are multiple equilibrium allocations of labour towards which the economy may converge in the long-run depending on the initial stock of natural resource and the initial distribution of labour. Under decentralized resource management, the level of extraction set by the government of the resource region is higher than in the federal optimum, which tends to enlarge the set of initial conditions under which the economy converges to the low-income equilibrium in the long-run. The optimal path of extraction from the perspective of the federation satisfies a modified Hotelling's rule that takes into account the impact of resource extraction on manufacturing production.

The Role of Conflict for Optimal Climate and Immigration Policy

Fabien Prieur

Toulouse School of Economics Université Toulouse Capitole (INRA)

e-mail: prieur@supagro.inra.fr

Ingmar Schumacher

IPAG Business School Paris

e-mail: prieur@supagro.inra.fr

Discipline: Economics and Game Theory

Keywords: climate change, immigration, conflict, mitigation.

JEL Classification: Q54, Q56, F22.

In this article we investigate the role that internal and external conflict plays for optimal climate and immigration policy. To do so we develop a model in which we take the perspective of the North who unilaterally chooses the number of immigrants from a pool of potential migrants that is endogenously determined by the extent of climate change. Accepting these migrants allows increases in local production which not only increases climate change but also gives rise to internal conflicts. In addition, those potential migrants that want to move due to climate change but that are not allowed to immigrate may induce significant external conflict.

We discuss the welfare losses from wrongly ignoring the existence of external or internal conflicts. Furthermore, we examine the substitutability vs complementarity between the mitigation and immigration policy. We show how the initial level of CO₂ may give rise to very different optimal paths.

The Transmission of Localised Productivity and Weather Shocks in a Globalised World

Mirabelle Muûls

Imperial College London, Grantham Institute and Business School

e-mail: m.muuls@imperial.ac.uk

Ulrich Wagner

University of Mannheim, Economics Department

Ralf Martin

Imperial College London, Business School

Jonathan Colmer

London School of Economics, Centre for Economic Performance

Discipline: Economics and Game Theory

Keywords: weather shocks, productivity, supply chains

JEL Classification: D22, F14, F61, Q54

This paper seeks to quantify the direct effects of local productivity shocks on firms, as well as the indirect effects through supply chain networks. We construct a unique dataset linking data on the economic performance and global trade transactions of French manufacturing firms with global weather data. Exploiting firm-level variation in exposure to both domestic and foreign weather shocks, we estimate both the local and linkage effects of weather on the economic performance of manufacturing firms in France. We observe that domestic exposure to higher temperatures is associated with a reduction in the production of manufacturing firms. On the demand side, we estimate that increases in rainfall downstream results in an expansion in the production of upstream firms, suggesting that firms are able to increase their market share in response to localised productivity shocks in downstream markets. On the supply side, we observe that, on average, weather variation upstream has little effect on downstream production. However, we show that this effect is heterogeneous across firms, finding that firms with a greater initial import share from developing countries experience a relative contraction in production in response to increases

in temperature upstream. This effect is attenuated for firms with a greater initial import-share from countries with greater access to air conditioning, indicating that the effect of temperature on production in these countries is due to thermal stress. These results suggest that localised productivity shocks can have significant economic effects across countries, and that if we fail to account for the interconnectedness of firms and sectors we may substantially underestimate the consequences of short-run weather and future climate change on economic activity.

Hysteresis and the Social Cost of Corrective Policies: Evidence from a Temporary Energy Saving Program

Francisco Costa
FGV/EPGE

François Gerard
Columbia University
e-mail: fgerard@columbia.edu

Discipline: Economics and Game Theory

JEL Classification: D62, H23, Q50

This paper studies how one may overestimate the social cost of a long-run corrective policy by neglecting the possibility of hysteresis, i.e., that the policy in earlier periods may have a persistent impact in the long run. In a price-theoretic framework, we show that one statistic is key to evaluating this bias: the long-term impact of a similar but temporary policy that was known to be temporary. We then provide evidence of the importance of hysteresis, and estimate such a statistic, for a policy-relevant behavior: residential electricity use in a developing country context. We study the 10-year impact of a 9-month long policy in Brazil, which aimed at large temporary reductions in residential electricity use. Through a difference-in-difference strategy, we exploit the fact that customers of some distribution utilities were not subject to the policy. Using utility-level administrative data, we find that the temporary policy led to a long-run and stable reduction in average electricity use of 11%, or about half of the short-run impact. Using individual monthly billing data for one distribution utility, we find that 69% of customers were still consuming less electricity four years after the policy ended. Household-level microdata suggest that the main mechanism of hysteresis is a persistent change in consumption habits. Incorporating our estimates into this framework illustrates that, by neglecting the possibility of hysteresis, one could dramatically overestimate the social cost of long-run corrective policies.

How Far Should EPR Reach? Exports of Used Goods to Developing Countries

Johan Eyckmans

KU Leuven

e-mail: johan.eyckmans@kuleuven.be

Discipline: Economics and Game Theory

This paper uses a stylized economic model to assess how incentives for exports and recycling of used durable goods are affected by the interaction of several waste policy instruments, in particular Extended Producer Responsibility (EPR), waste disposal taxes and excise duties. The model shows that high waste disposal taxes weaken EPR effectiveness and that the interaction of EPR with disposal taxes is likely to increase the global volume of waste. Under standard EPR schemes, disposal taxes do not increase recycling rates but only stimulate exports of used durable goods to developing countries where waste management is typically poorly developed. The model shows that the global first-best outcome can only be achieved if EPR obligations are extended to cover also exported used goods and should be combined with excise duties. In that case, waste disposal taxes should not be used anymore in order to avoid excessive incentives for exports.

Evaluation of Long-dated Assets: The Role of Parameter Uncertainty

Christian Gollier

Toulouse School of Economics, Université de Toulouse-Capitole

e-mail: christian.gollier@tse-fr.eu

Discipline: Economics and Game Theory

Keywords: Term structure, risk premium, decreasing discount rates, uncertain growth, rare events, long-run risk

JEL Classification: G11, G12, E43, Q54

We examine the term structures of efficient risk-adjusted discount rates when the random walk of economic growth is affected by parametric uncertainty, with an application to the valuation of the social cost of carbon. Our results are generic in the sense that they do not rely on any structural assumption underlying this uncertainty. We show that parametric uncertainty does not affect the discount rates to be used to value very short zero-coupon bonds and equity. Moreover, it makes the term structure of the risk-free rates decreasing. The term structure of aggregate risk premia is increasing when the uncertain cumulants of log consumption are independent. Under some conditions, the term structure of risk-adjusted discount rates is increasing if and only if the asset's beta is larger than two times the relative risk aversion. We apply these generic results to the case of an uncertain probability of macroeconomic catastrophes à la Barro (2006), and to the case of an uncertain trend or volatility of growth à la Veronesi (2000) and Weitzman (2007). We show that these sources of uncertainty have a strong effect on efficient long-term discount rates.

Revisiting the Problem of Procurement of a Pure Public Good: Beyond VCG Mechanism

E. Athanasiou
New Economic School
e-mail: eathanasiou@nes.ru

Yves Sprumont
University of Montreal

Giacomo Valletta
CORE, Université catholique de Louvain

Discipline: Economics and Game Theory

We consider the problem of making public binary decisions. The consequences of the decision are non-excludable and non-rivalrous. Hence the adjective ‘public’. The decision takes the form of either accepting or rejecting a proposal. Hence the term ‘binary’.

A set of agents have quasilinear preferences over the two possible outcomes and money. Hence, each agent’s evaluation can be captured by single real number. This number may be positive, negative or zero reflecting respectively a positive disposition towards the proposal, a negative one or indifference.

The object of our investigation are mechanisms that associate to each profile of agents’ valuations a decision (either ‘yes’ or ‘no’) along with a transfer of money for each agent. An individual transfer takes the form of a real number.

We impose two properties on the mechanisms we consider: *Strategy-proofness* and *Anonymity*. The former requires that at each profile of valuations each agent, if asked, has an incentive to declare her valuation truthfully independently of whether other agents will do the same. The latter requires that the name of the individual does not matter for his personal outcome. The starting point of our paper is a characterization of the set of *Strategy-proof* and *Anonymous* mechanisms.

The set of *Strategy-proof* and *Anonymous* mechanisms is rich and allows for many possibilities. The novelty in our approach is that we use this set to raise the following question: What is the set of *Strategy-proof*

and *Anonymous* mechanisms that are not Pareto dominated by another *Strategy-proof* and *Anonymous* mechanism? It is important to note that by raising the question in those terms we make no a priori commitment to *efficiency* or to *budget balancedness*. Instead, we explore the trade-off between those two competing goals.

The main aim of the paper is recover a second-best frontier of sorts. Although our work is very much in progress there are some key points that we may emphasize at this stage. First, this second-best frontier includes some but all possible Vickrey-Clarke-Groves mechanisms. Second, mechanisms that are not *decision efficient* may be second-best efficient. Third, there exist mechanisms that do not utilize transfers (they assign a transfer equal to zero to each agent at each profile of valuations) that are second-best efficient.

The Right to Secede: The Political Economy of Exit Clauses

Martijn Huysmans

KU Leuven, LICOS Centre for Institutions and Economic Performance

e-mail: martijn.huysmans@kuleuven.be

Christophe Crombez

KU Leuven & Stanford University

Discipline: Economics and Game Theory

Keywords: Exit, Secession, Dynamic Games, Markov Perfect Equilibrium

JEL Classification: C73, P48

This article presents a political economy analysis of exit clauses in political agreements between heterogeneous entities. By being part of the agreement each entity receives a benefit flow that is determined by its type and the stochastic state of the world. The state follows a Brownian Motion. In some state realizations one or both entities may wish to exit from the agreement. In the absence of exit clauses, exit is only possible through renegotiation or a secession war. Exit clauses, by contrast, pre-specify at the time of the initial agreement a cost of ending the agreement unilaterally.

Exit clauses are a common feature of agreements among individuals. Examples include termination clauses in employment contracts and prenuptial contracts pre-specifying the conditions of a potential divorce. While they are not common in political agreements, some examples do exist: Article 50 of the Treaty of Lisbon gives European Union (EU) member states a right to exit, and the Ethiopian constitution contains a secession clause.

Based on the Markov Perfect Equilibrium of a stochastic dynamic game, we derive the ex-ante expected effect of exit clauses on individual and social welfare. We show that under complete information and in the presence of stochastic shocks there is always an exit clause that the proposer is willing to offer. Moreover, if ex-post renegotiation is politically infeasible, strongly

Pareto-improving exit clauses exist. This runs counter to the dominant point of view in the constitutional political economy literature that exit clauses in political agreements should be avoided.

Applications of the theory include trade agreements, currency unions and (con)federations. Hence the theory sheds light on current issues of secession and exit, such as Grexit (exit by Greece from the Eurozone), Brexit (exit of the United Kingdom from the European Union) and the independence movements in Scotland and Catalonia.

Choosing When to Delegate: Endogenous Cooperation and Optimal Voting Rules

Antonin Macé
CNRS & Aix-Marseille School of Economics
Rafael Treibich
University of Southern Denmark

Discipline: Economics and Game Theory

Keywords: Committees, Coalition formation, International unions

We develop a model of collective decision making in which a group of countries may choose to delegate part of their national sovereignty on specific areas (environmental regulation, competition policy, national defense, etc.). Such cooperation then implies making repeated collective decisions at a qualified majority. The choice of integration reflects a basic trade-off between the benefit of coordination externalities and the cost of disagreeing with the collective decision. With a constitutional design perspective, we discuss the relevance of flexible participation rules, where a strict subset of countries may cooperate while the others remain sovereign. We show that these rules allow for a deeper level of integration, and this generates a higher level of social welfare. Then, we show how the constitutional choice of the voting rule, here a majority threshold, can enhance or reduce the degree of cooperation.

Sharing the proceeds from a hierarchical venture

Jens Leth Hougaard

University of Copenhagen, Department of Food and Resource Economics

Juan D. Moreno-Ternero

Universidad Pablo de Olavide, Department of Economics
and Université catholique de Louvain, CORE

Mich Tvede

Newcastle University Business School

Lars Peter Østerdal

University of Southern Denmark, Department of Business and Economics
University of Southern Denmark, COHERE.

Discipline: Economics and Game Theory

Keywords: Hierarchies, Joint ventures, Resource allocation, Transfer rules, MIT strategy

JEL Classification: C71

We consider the problem of distributing the proceeds generated from a joint venture in which the participating agents are hierarchically organized. We introduce and characterize a family of allocation rules where revenue ‘bubbles up’ in the hierarchy. The family is flexible enough to accommodate a *no-transfer* rule (where no revenue bubbles up) and a *full-transfer* rule (where all the revenues bubble up to the top of the hierarchy). Intermediate rules within the family are reminiscent of popular incentive mechanisms for social mobilization. Our benchmark model refers to the case of linear hierarchies, but we also extend the analysis to the case in which hierarchies may convey a general tree structure and include joint ownerships.

For more details, the reader is referred to the CORE DISCUSSION PAPER 2015/31

Firm's Financialization vs Profit Maximization

B. Cresti

Université catholique de Louvain, Faculté de Psychologie et des Sciences de l'Éducation
e-mail: barbara.cresti@uclouvain.be

F. Menoncin

University of Brescia, Department of Economics and Management
e-mail: francesco.menoncin@unibs.it

Discipline: Operations Research

Keywords: Firm Behavior, Profit Rates, Firm Objectives, Profit Maximizing, Entrepreneurship, Financial

JEL Classification: D210, L210, L260

We model the investment/production decision of a firm aiming at maximizing the expected present utility of dividend flows paid to its stockholder/entrepreneur, until its (stochastic) time of default. When bankruptcy happens, the firm ceases to exist, all the remaining assets are paid to firm's creditors, and no more dividends are paid. The stockholder's preferences are implemented in the firm's objective function and we assume that there exists a minimum level of dividend that the stockholder does want to maintain over time.

Moreover, we also model the investment/financial problem of the firm as follows: the firm's borrowing and investment strategies to ensure production are set once and for all at time t_0 and cannot be modified before time T . Instead, the financial investment decision is continuously adjusted over the interval $[t_0, T]$ in order to manage/hedge the financial risk. Indeed, over all the management period, the firm is subject to a default risk.

The risky environment the firm works on is fully described by diffusion processes driving three stochastic state variables: (i) the riskless interest rate, (ii) the force of default, (iii) and the firm's idiosyncratic risk.

The value of the firm is a stochastic process which is incremented by the return on investments and reduced by both the service on debt (which cannot be renegotiated until time T) and the dividends/withdrawals paid to the stockholder.

The control variables are both the dividends paid to the stockholder and the portfolio allocation of financial assets. These assets are given by: (i) a riskless asset, (ii) a bond as a derivative on the interest rate, and (iii) a stock index correlated with the firm's idiosyncratic risk. The initial (at time t_0) amount of both debt and resources invested in the firm's production are given and contribute to generate risk that the firm must manage until time T .

We show that: (i) because of the bankruptcy risk, the investment strategy of the firm is more prudential, (ii) the riskiness of the firm's portfolio changes over time and generates a sort of cycle in the management behavior towards risk between time t_0 and T , (iii) it is optimal for the stockholder to receive dividends proportional to the firm's value reduced by the expected present value of all the future services on firm's debt, net of the firm's return. Finally, a numerical simulation allows us to show the optimal proportion of financial assets in firm's portfolio.

Order Sequencing with Unreliable Forecasts to Minimize Cash Lead Time

Philippe Chevalier

Université catholique de Louvain, CORE

e-mail: philippe.chevalier@uclouvain.be

Wenli Peng

Université catholique de Louvain, CORE

e-mail: wenli.peng@uclouvain.be

Discipline: Operations Research

Keywords: Forecast Sharing, Make-to-Forecast Supply Chain, Integration of Supply Chain Information Flows and Cash Flows, Sequencing, Stochastic Scheduling, Hybrid Algorithm

Forecast sharing is one of the major activities in supply chain collaboration. Ideally, it should lead to a win-win situation: using forecast information, the supplier deploys enough production capacity to address potential demand, and in turn, the buyer secures a dependable supply source. However, in practice, this benefit is often compromised due to forecast imprecision. Our objective is to study the impact of forecast (in)accuracy from a supplier's perspective. To ensure a high service level, a supplier must include more safety time in the quoted lead time in response to less reliable orders, which implies a delay in revenue realization. Consequently, the supplier would prefer to serve buyers that provide credible forecasts before serving those communicating "cheap talk". Nevertheless, the link between forecast error and delayed cash inflow is not obvious. In this paper, we explore the relationship between supply chain information flows and cash flows. Our first contribution is to provide some analytical support to the managerial intuition that forecast errors are detrimental to the supply chain performance and that a more reliable buyer should be prioritized. We also develop an efficient algorithm to find the optimal sequence that minimizes the average cash delay given the buyer's unreliability.

Integer Programming: The Global Impact

George Nemhauser
Georgia Institute of Technology
e-mail: gn3@gatech.edu

Discipline: Operations Research

Integer programming is used to solve planning and operational problems in energy, finance, health, manufacturing, military, transportation, and in almost any imaginable domain where decisions are made. Currently available software is capable of solving models with thousands, and sometimes millions, of variables and constraints. Most Fortune 500 companies use integer programming in some aspects of their business. We will review the development of integer programming algorithms and applications, discuss some developments, including those done at CORE, that have had big impact in solving important problems, and present recent progress that has made it possible to solve very large instances and to obtain provably good solutions quickly. We'll close by speculating on future advances in methodology and applications.

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