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## **d/SEAS WORKING PAPERS**

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### **Vol 1 No 2 (2018): New Frontiers**

*inside volume / nel volume*

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# Editorial/Editoriale

We proudly announce that scholars from around the world very well received the dissemination of the d/Seas Working Papers through both SSRN and Unipa platforms. The launching of the inaugural issue has been such encouraging results. We summarise the top results as follow. Downloads are being from all the five continents. In the last six months, the department's papers have had about 12,000 unique visitors and over 2500 downloads have been done. The subscribers of the WPs are distributed widely and globally as best as each word is testified by the map above. Now, this Volume (n.2, 2018) offers a selection of papers both in economic and statistical fields. We propose both empirical and theoretical research that open up new scenarios and that, for this reason, all of them are fully entitled to recall the title New frontiers to which this volume is dedicated.



Inside the economics section –

Biagio Bossone, Massimo Costa, Andrea Cuccia e Giuseppe Valenza (Accounting meets economics: towards an 'accounting view' of money) study embodies the spirit of the Volume since it concerns the foundations of the "Accounting View" of money. The study that uses international accounting principles argues that state and central bank monies are not debt and that in fractional reserve regimes only a share of commercial bank money can be regarded as debt. The study determines how the seigniorage associated with the issuance of these monies should be accounted for in the financial

statements of the issuing institutions, and examines what this implies for the correct understanding of money. The new view throws light into such issues as the true nature of central bank capital, commercial banks, and digital currencies. From there, authors derive and apply new measurements of seigniorage to the case of the UK (for which recent estimates exist). The results reveal that seigniorage, in particular, that extracted by commercial banks, is a quantitatively relevant phenomenon.

The Andrea Consiglio, Massimo Attanasio, Stefano Fricano and Antonio Pecorella's empirical study (A Maximum Demand Coverage Model for the Optimal Location of the AMAT's Bike Sharing Stations) about the AMAT's bike-sharing service discloses new horizons as well. Within a sustainable mobility project, it has involved the DSEAS and four secondary schools to the research project "GoToSchool", a project whose main aim is to foster the use of the bike by the students in getting to the school. The project developed in two phases: the first phase was devoted to the estimate of the demand of bike-sharing service from the students; the second phase was committed to the study of an optimal facility allocation problem in order to maximise the demand of bike-sharing service is arising from students. The optimisation model can be easily customised to account for operational requirements from AMAT, such as, the maximum number of bike-sharing stations that can be installed according to the available budget, the inclusion or exclusion ("blacklist" or "whitelist") of potential bike station places because of specific planning and organisational needs. Finally, the model provides a tool to evaluate some fundamental parameters such as the utility to reach school by bike, or the distances between the students home address and the places of the potential bike stations.

Massimo Costa and Francesca Cimò (From Cash to Accrual Accounting: The seminal case of the Sicilian Regional Public Bodies) trace the progressive introduction of a complete accrual accounting by the Sicilian Regional public bodies – within the context of international and national public management changes – pursuing the ultimate goal to improve efficiency, accountability and transparency. After a close examination of the critical choices made by a Committee established for this purpose, the work investigates about the need to go beyond a "simple" accrual basis accounting system especially in a context where concepts like the inter-institutional horizon and public value are more and more relevant.

Gioacchino Fazio e Stefano Fricano (A Note on Economic Impact of EFF on Sicilian Firms Performance) investigate the measure 2.3 of the European Fisheries Fund in Sicily. Since it has claimed investments of fish firms in production capacity expansion and modernisation of fish processing, they analyse both whether or not such investments have been effective in sup-

porting the competitiveness of these firms and whether they have influenced the economic sustainability of the regional seafood chain. They propose a counterfactual analysis for contributing to those assessments through comparison of business performance between funded and non-funded firms.

Last but not least, Ieva Mikaliunaite and Andrea Cipollini (Financial distress and real economic activity in Lithuania: a Granger causality test based on MF-VAR) first, extend the monthly Financial Stress Index (FSI) for Lithuania computed by ECB to a high-frequency (daily) horizon, and they also include the banking sector among its constituents (beyond bond, equity, foreign exchange markets). The empirical results suggest no evidence of Granger causality between the monthly FSI index and monthly industrial production growth. On the contrary, a Granger causality test applied to a VAR using mixed frequency data characterised by a significant mismatch in sampling frequencies of the series involved (i.e. daily vs monthly), suggests that the daily Lithuanian FSI has a predictive power for monthly Lithuanian IP growth for the full sample period (October 2001 – December 2016), but not vice versa. Full sample results are confirmed by rolling-window analysis.

Inside the statistic section –

Ornella Giambalvo and Roberto Sichera (A Proposal to estimate the roaming-dog Total in an urban area through a PPSWOR spatial sampling with a sample size greater than two.) deal with risks dogs roaming in urban areas constitute for public order, hygiene and health. Authors face the issue of a lacking reliable statistical procedure aimed to measure such population available in literature as the problem to solve. The paper presents a simple, reproducible survey sampling procedure to estimate the number of roaming dogs in an urban area through the description of a real study carried out on a restricted area of the city of Palermo, in southern Italy. A sample of areas is drawn using a drawn-by-drawn spatial sampling with probabilities proportional to the size and without replacement (PPSWOR). As inclusion probabilities are not available in closed form, they are estimated by Monte Carlo approach, which is of simple implementation and permits design-based variance estimation even when first-order inclusion probabilities are unknown.

Mariangela Sciandra, Antonio D'Ambrosio and Antonella Plaia (Projection Clustering Unfolding: a new algorithm for clustering individuals or items in a preference matrix) cope with the use of decision tree for clustering preference vectors. Starting from the fact that a decision trees are useful and intuitive, but they are very unstable: small perturbations bring significant changes, authors propose the use of more stable procedures in order to clustering ranking data. In this work, a Projection Clustering Unfolding (PCU) algorithm for preference data will be proposed in order to extract useful information in a low-dimensional subspace by starting from a high but mostly

empty dimensional space. Comparison between unfolding configurations and PCU solutions will be carried out through Procrustes analysis.

In the next issues –

We are scheduling two Volumes for 2019 — the third one with a selection of primary researches and seminars supported by and hosted by department respectively; one special issue will host a selection of commented rejected papers. We hope this recent initiative could trigger a hot, lively and exciting debate. Stay tuned!

The editor in chief

Calogero Massimo Cammalleri

Annunciamo orgogliosamente che la disseminazione dei Working Papers del dipartimento attraverso la doppia piattaforma SSRN e Unipa è stata ben accolta dagli studiosi di tutto il mondo. Il lancio del volume inaugurale ha avuto un riscontro molto incoraggiante. Ne riassumiamo qui di seguito i più significativi. Il download dei paper attraverso la piattaforma SSRN ha interessato tutti e cinque i continenti, con una netta prevalenza dell'Europa Centrale, inclusa la Gran Bretagna. Negli ultimi sei mesi i paper del dipartimento hanno totalizzato circa 12.000 visitatori unici e 2500 download. I sottoscrittori dei WPs sono distribuiti capillarmente e globalmente come meglio di ogni parola testimonia la mappa sopra riportata. Incoraggiati da questi risultati pubblichiamo il secondo Volume (2018) che raccoglie una selezione di paper che concernono ricerche del dipartimento in area economica e statistica. Si tratta di ricerche empiriche o teoriche che aprono nuovi scenari e che per questo stanno tutte a pieno titolo sotto in questo volume dal titolo *New frontiers*. I paper sono ordinati per sezione e all'interno della sezione in ordine alfabetico di primo autore.

Nella sezione economia -

Lo studio di Biagio Bossone, Massimo Costa, Andrea Cuccia e Giuseppe Valenza (*Accounting meets economics: towards an 'accounting view' of money*) incarna lo spirito del Volume occupandosi di definire le fondamenta dell' "Approccio Contabile" ("Accounting View") alla moneta. Per mezzo dei principi di Ragioneria Generale riconosciuti internazionalmente, lo studio argomenta che le monete emesse dallo Stato e dalla banca centrale non costituiscono debito, e che nei regimi di riserva frazionaria soltanto una quota della moneta emessa dalle banche commerciali può essere considerata quale debito. Lo studio determina come il signoraggio associato all'emissione di queste monete dovrebbe essere contabilizzato nei bilanci delle istituzioni emittenti ed esamina le implicazioni di ciò per la corretta comprensione della moneta. Il nuovo approccio getta luce su argomenti quali la vera natura del capitale della banca centrale, le monete delle banche commerciali e quelle digitali. Partendo da ciò, gli autori derivano nuovi metodi di stima del signoraggio che applicano al caso del Regno Unito (per il quale esistono stime recenti). I risultati rivelano che il signoraggio, in particolare quello estratto dalle banche commerciali, è un fenomeno quali-quantitativamente rilevante.

Nuovi orizzonti apre pure lo studio empirico di Andrea Consiglio, Massimo Attanasio, Stefano Fricano e Antonio Pecorella (*A Maximum Demand Coverage Model for the Optimal Location of the AMAT's Bike Sharing Stations*) sul servizio di bike-sharing dell'AMAT (l'azienda dei trasporti pubblici del Comune di Palermo). Nell'ambito di un progetto di mobilità sostenibile fornisce innovativi e interessanti criteri per espandere la rete di bikesharing con l'obiettivo principale di favorire l'utilizzo della bici da parte degli studenti

delle scuole medie superiori. Gli autori propongono un modello matematico di ottimizzazione che permette di introdurre vincoli che tengano conto delle esigenze del committente riguardo alla numerosità massima di ciclo-stazioni, all’inserimento in liste di inclusione o all’esclusione ( “blacklist” o “whitelist”) di un elenco di potenziali ciclo-stazioni per motivi legati a specifiche esigenze organizzative e progettuali, e alla valutazione dell’impatto di alcuni parametri fondamentali, quali l’utilità che ha per uno studente il recarsi a scuola utilizzando la bicicletta, oppure, la distanza dalle ciclo-stazioni dell’indirizzo di residenza .

Massimo Costa e Francesca Cimò (From Cash to Accrual Accounting: The seminal case of the Sicilian Regional Public Bodies) tracciano gli effetti della progressiva introduzione di una contabilità per competenza completa da parte degli enti pubblici regionali siciliani - nel contesto dei cambiamenti di gestione pubblica internazionali e nazionali - perseguendo l’obiettivo finale di migliorare l’efficienza, la responsabilità e la trasparenza. Dopo l’esame delle principali scelte fatte da un comitato istituito a tale scopo, il lavoro indaga sulla necessità di andare oltre un sistema contabile di contabilità semplice per competenza, specialmente in un contesto in cui concetti come orizzonte interistituzionale e valore pubblico sono più e più rilevanti. Nello studio vengono presentate le prove empiriche del caso siciliano analizzato da un punto di vista critico che conduce al suggerimento di introdurre un quadro contabile che tenga conto dei tre pilastri della sostenibilità : quelli sociali, ambientali e finanziari.

Ancora, Gioacchino Fazio e Stefano Fricano (A Note on Economic Impact of EFF on Sicilian Firms Performance ) indagano l’efficacia in Sicilia della misura 2.3 (Investimenti nei settori della trasformazione e commercializzazione) del programma operativo Fondo Europeo per la Pesca (FEP 2007-2013) che ha sostenuto finanziariamente gli investimenti mirati ad ampliare la capacità produttiva e l’ammodernamento degli impianti delle imprese della trasformazione dei prodotti ittici. Gli autori si chiedono in che misura tali interventi siano stati efficaci nel sostenere la competitività del settore della trasformazione dei prodotti ittici e in che modo abbiano inciso sulla sostenibilità economica della filiera ittica regionale. Lo studio proposto contribuisce a tale valutazione attraverso un’indagine esplorativa presso le imprese beneficiarie dei contributi pubblici e un’analisi della variazione delle loro performance aziendali.

In ultimo, ma non in ordine di importanza, Ieva Mikaliunaite e Andrea Cipollini (Financial distress and real economic activity in Lithuania: a Granger causality test based on MF-VAR) estendono l’applicazione dell’indice mensile di stress finanziario (FSI) per la Lituania calcolato dalla BCE ad un orizzonte ad alta frequenza (giornaliero), includendo anche il settore bancario



tra i suoi costituenti (oltre i mercati obbligazionari, azionari, dei cambi). Ot tengono risultati empirici che non suggeriscono alcuna evidenza di causalità di Granger tra l'indice FSI mensile e la crescita mensile della produzione industriale. Al contrario, il test di causalità Granger, applicato a un VAR utilizzando dati a frequenza mista caratterizzati da una grande discrepanza nelle frequenze di campionamento della serie coinvolte (cioè giornaliero vs mensile), suggerisce che l'FSI lituano giornaliero ha un potere predittivo per la crescita mensile della produzione industriale lituana per l'intero periodo di campionamento (ottobre 2001 - dicembre 2016), ma non viceversa. Queste conclusioni sono poi confermate dall'analisi rolling-window.

Nella sezione Statistica –

Ornella Giambalvo e Roberto Sichera (A Proposal to estimate the roaming-dog Total in an urban area through a PPSWOR spatial sampling with sample size greater than two.) si occupano del rischio che cani che vagano sul territorio possono rappresentare per l'uomo. Gli autori considerano assumono la nota criticità della strategia di contrasto più in uso – quello dell'assenza in letteratura di una metodologia statistica adeguata al censimento dei randagi presenti su un dato territorio (cioè cattura, sterilizzazione e successivo rilascio) come il problema da risolvere. In questo articolo presentano un'indagine campionaria per la stima del totale di cani randagi tramite uno studio condotto nella prima circoscrizione della città di Palermo. I dati sono stati raccolti su un campione di aree selezionato per mezzo di un campionamento probabilistico con probabilità variabili, anche ricorrendo a una stima tramite lacan lye simulazione Monte Carlo e l'algoritmo di Bennett (Fattorini, 2009).

Mariangela Sciandra, Antonio D'Ambrosio e Antonella Plaia (Projection Clustering Unfolding: a new algorithm for clustering individuals or items in a preference matrix) riprendono il tema dell'uso degli alberi decisionali per il raggruppamento dei vettori di preferenze. A partire dalla constatazione che nell'ambito delle classifiche di preferenza gli alberi decisionali benché utili e intuitivi sono anche molto instabili: piccole perturbazioni possono condurre a grandi cambiamenti, gli autori propongono di utilizzare procedure più stabili al fine di raggruppare i dati di ranking. Nel lavoro che pubblichiamo essi, partendo da uno spazio dimensionale alto ma per lo più vuoto, esperimentano un algoritmo di Projection Clustering Unfolding (PCU) per i dati delle preferenze per estrarre informazioni utili in un sottospazio a bassa dimensione e, per mezzo di un'analisi procustiana, concludono con il confronto tra le configurazioni di proiezione e le soluzioni PCU.

Nei prossimi numeri –

Nel 2019 prevediamo di pubblicare due volumi. Il terzo volume dei d/Seas Working Papers Series con una selezione delle principali ricerche condotte, e dei principali seminari tenuti, nel corso dell'anno nel Dipartimento e un

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numero speciale destinato ai rejected papers. Un'iniziativa quest'ultima che, auspichiamo, farà molto discutere. Stay tuned!

Il direttore  
Calogero Massimo Cammalleri

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# Working Papers

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## Accounting meets economics: towards an 'accounting view' of money

Biagio Bossone · Massimo Costa · Andrea  
Cuccia · Giuseppe Valenza

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**Abstract** This study lays the foundations of the “Accounting View” of money. Using international accounting principles, the study argues that state and central bank monies are not debt, and that in fractional reserve regimes only a share of commercial bank money can be regarded as debt. The study determines how the seigniorage associated with the issuance of these monies should be accounted for in the financial statements of the issuing institutions, and examines what this implies for the correct understanding of money. The new view throws light into such issues as the true nature of central bank capital, commercial banks, and digital currencies. Drawing on it, new measurements of seigniorage are derived and applied to the case of the UK (for which recent estimates exist). The results reveal that seigniorage, in particular that extracted by commercial banks, is a quantitatively relevant phenomenon.

**Keywords** Central bank money and capital · commercial banks · deposits · debt · equity · seigniorage.

**Riassunto** *Questo studio pone le fondamenta dell' “Approccio Contabile” (“Accounting View”) alla moneta. Sulla base dei principi di Ragioneria Generale riconosciuti internazionalmente, lo studio argomenta che le monete emesse dallo stato e dalla banca centrale non costituiscono debito e che nei regimi di riserva frazionaria soltanto una quota della moneta emessa dalle*

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*banche commerciali pu essere considerata quale debito. Lo studio chiarisce come il signoraggio associato all'emissione di queste monete debba essere contabilizzato nei bilanci delle istituzioni emittenti ed esamina le implicazioni di ciò per la corretta comprensione della moneta. Il nuovo approccio fa luce su argomenti quali la vera natura del capitale della banca centrale, le monete delle banche commerciali e quelle digitali. Da esso si derivano nuovi metodi di stima del signoraggio e si applicano al caso del Regno Unito (per il quale esistono stime recenti). I risultati rivelano che il signoraggio, in particolare quello estratto dalle banche commerciali, un fenomeno quantitativamente rilevante.*

**Parole chiave** *Moneta e capitale delle banche centrali - banche commerciali - depositi - debito - patrimonio netto - signoraggio.*

## 1 Introduction

Coins circulating as legal tender in national jurisdictions worldwide are treated as debt liabilities of the issuing states and reported as a component of public debt under national accounting statistics (ESA, 2010). Similarly, banknotes issued by central banks and, by extension, central bank reserves are accounted for as debt owed by the central banks to the banknote and reserve holders, respectively. A fortiori, demand deposits issued by commercial banks to their clients are considered as debt liabilities of the issuing banks and represent the counterparts to the value held by depositors on the demand deposit accounts with those banks.

In fact, although the law says that money is “debt,” a correct application of the existing accounting principles raises serious doubts about such conception of money. Debt involves obligations to transfer economic resources from borrowers to lenders (IASB, 2018). Yet, for the state, which obligation derives from the public holding coins? Or, for the central bank, which obligation derives from the holders of banknotes or the banks holding reserves? And in the case of commercial bank deposits, how does their nature of debt obligations relate to the circumstance that, in fractional reserve regimes with central banks acting as lenders of last resort, a large share of such deposits will never be redeemed for cash or other settlement instruments – with an almost absolute degree of certainty? Moreover, aren't non-debt money liabilities a source of income for their issuers (also known as “seigniorage”), which originates from the power to issue money at a cost that is lower than the attendant revenue? If so, how should issuing institutions account for these sources of income?

This study is about establishing the true nature of all the above forms of money once it is clarified that they are not debt liabilities. Proceeding separately for the case of monies issued by the state and the central bank and those issued by commercial banks and other private-sector entities (e.g., digital currencies), respectively, the study will determine the correct way to account for them in the financial statements of the issuing institutions. The study will also clarify what the different accounting treatment implies for a correct understanding of the concept of money (hence, the name of “Accounting View” of money that we propose for

our approach), and will evaluate the financial implications of the new understanding. Finally, drawing on the implications of the new approach, the study will derive new measurements of the seigniorage extracted by the state, the central bank, and commercial banks, respectively, and will provide empirical estimates to assess the quantitative significance of seigniorage in contemporary economies.

More broadly, this study aims to resolve the apparent inconsistency between the formal rules of reporting money liabilities in the financial statements of the issuing institutions, on the one hand, and the economic substance of the money liabilities to be reported in the statements, on the other. Resolving this inconsistency requires a dynamic interaction between Accounting and Economics – the greatest ambition of our proposed approach: only Accounting can fill in the gap, provided that Economics brings it to the open. The general lack of communication between the two disciplines has caused the inconsistency to persist unaddressed for decades.

In point of methodology, while accounting practices vary across countries, and in particular across central banks (Archer and Moser-Bohem, 2013), this study takes as reference the new *Conceptual Framework for Financial Reporting* (henceforth, “Framework”), which underpins the *International Financial Reporting Standards* (IFRS). The IFRS reflect the best wisdom that the international financial community has come to express, with a view to ensuring transparency and consistency between the form of reporting rules and the substance of the economic facts to be reported.

The study is organized as follows. Section 2 reviews the literature on the practices currently in use to account for money in the balance sheet and financial statement positions of money issuers; the section also reviews the literature on seigniorage (including that on commercial banks). Section 3 describes the new “Accounting View” of money, it shows how different types of money should be understood according to the new approach and identifies the sources of seigniorage deriving from the power to issue money; the section, then, points to how the types of money being discussed should be treated based on the relevant international accounting principles. Section 4 identifies new measurements of seigniorage and applies them to the case of the UK (for which recent estimates are available). Section 5 concludes the study.

## 2 Review of the Literature

The accounting literature on money liabilities is rather scant, as shown by the recent survey on financial accounting practices by Beatty and Liao (2014). The reason for this lack of interest by the community of scholars has historical roots: originally, money liabilities were plain debt liabilities and were allocated as such in the financial statements of the issuing institutions: there was no point in further investigating their nature. *Inertia has done the rest.*

On the accounting of central bank money, the only contribution that is relevant to our study is the work by Archer and Moser-Boehm, which replaces the narrow concept of equity capital with the broader one of “positive comprehensive net worth”, which, in addition to conventional shareholder equity, includes the stock of banknotes outstanding and the present value of future

seigniorage income. In particular as regards banknotes, the authors argue that they "...act more like equity capital than debt obligations. As they bear no interest and are perpetual in character, they provide a stable funding base for income generation. To the extent that net income can be retained when needed, a large share of banknote liabilities provide a base for rebuilding equity if it has been depleted by a negative shock. (pp. 33-34). Archer and Moser-Boehm, however, do not dig further into this line of enquiry and do not extend the sources of income beyond banknotes, what we actually set out to do, *inter alia*, in this study.

No literature exists on the accounting treatment of commercial bank money (demand deposits), an issue that is totally disregarded by the international accounting standards (the International Financial Reporting Standards (IFRS) and the General Accepted Accounting Principles (GAAP)) as well as by existing national banking legislations.<sup>1</sup> Based on the general principle of "prevalence of substance over form", it seems here that, for reasons discussed in Section 2, the "form" of debt liability has prevailed over the substance of equity capital. However, for the purpose of our study the literature on hybrid financial instruments (that is, instruments that are partly debt liabilities and partly equity capital) is highly relevant. According to PAAinE (2008), Schmidt (2013), Fargher et al. (2016), and PWC (2017), the distinction between these two basic sources of funding is no longer as neat and sharp as it used to be, and calls into question the conventional definition of equity capital as the mere algebraic difference between assets and liabilities. For a company, in fact, equity capital is a source of funding much as debt liabilities are, with the difference that, unlike the latter, equity capital is not to be refunded to the company's owners unless and until the company enters into liquidation procedures.

The tax accounting literature (Flinn, 1999), too, is relevant for the purpose of our study, as the distinction it introduces between capital gains and revenue gains allows us to apply the accounting definition of hybrid financial instruments to commercial bank money liabilities, as discussed in Section 3.2.

Finally, our study builds on Costa (2009), which shows the historical process of gradual transformation of commercial bank money from debt liability to equity capital. While this process has already been completed for coins, banknotes and central bank reserves, it is to be considered "in progress" for commercial bank money.

Money as equity presupposes that seigniorage income accrues to money issuers. As regards state and central bank seigniorage, the literature is quite well known and extended (see Baltensperger and Jordan (1997a), Haslag (1998), Burdekin (2009), and the recent comprehensive review by Bjerg (2017)). Our study introduces new components into the definition and measurement of seigniorage; it also distinguishes between primary and secondary seigniorage in a way that conceptually resembles the distinction adopted by Bjerg et al. between monetary

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<sup>1</sup> For example, the "Debiti verso la clientela" in Italy, the "Opérations avec la clientèle" in France, and the "Customer accounts" in the U.K., are all represented as debt liabilities in accordance with their respective national legislations.



and opportunity cost seigniorage, but uses different definitions and measurements than theirs, based on the application of correct accounting principles.

Finally, concerning the seigniorage extracted by commercial banks, early references in the literature are Baltensperger and Jordan (1997b), and Bossone (2000, 2001). The topic has been quantitatively explored by Cardoso (2003), Arby (2006), Soldatos and Varelas (2015), and recently by Bjerg et al., and Macfarlane et al. (2017). As for the case of state and central bank seigniorage, our study introduces new definitions and measurements.

### 3 The “Accounting View” of money

The “Accounting View” of money reconsiders the various forms of money that are today commonly used worldwide as legal tender or as monies issued by commercial banks, and redefines their nature based on the correct application of the relevant international financial accounting principles and standards. We shall deal separately with legal tender and commercial bank money, respectively.

The approach can be applied to cryptocurrencies issued by the private sector.

#### 3.1 Legal Tender

Traditionally, and for a long time, sovereigns used to guarantee that coins issued contained specific amounts of precious metals. Later, banknotes gave holders the right to claim conversion into silver or gold (Costa, 2009). A similar obligation committed central banks to their reserve liabilities issued to commercial banks. All three species of money thus originated true debt obligations that were legally binding on their issuers.

Today, convertibility has all but disappeared for all three types of money. Coins have lost most of their relevance and have largely been replaced by paper money; convertibility of banknotes was suspended long ago; and the abandonment of the gold-exchange standard (about half a century ago) marked the demise of “debt” banknotes even at the international level. Finally, the reserve deposits held by commercial banks and national treasuries at central banks are today de-linked from obligations of conversion into commodities or third-party liabilities.<sup>2</sup> Therefore, although these monies are still allocated as debt in public finance statistics and central bank financial statements, they are not debt in the sense of carrying obligations that imply creditor rights.

*Accounting treatment* Issuing legal tender involves transactions whereby money is *sold* in exchange for other assets (even when it is exchanged against credit claims under lending contracts). The proceeds from money sales represent a form of income, specifically “revenue in-

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<sup>2</sup> Except where the central bank adheres to fixed exchange rate arrangements, the economy is dollarized, or the country is under a currency board regime.

come.”<sup>3</sup> Issuing legal tender thus generates income to the issuer. Under current accounting practices, this income is (incorrectly) unreported in the income statement of the central bank and is, instead, (incorrectly) set aside under the central bank’s “liabilities.”

In fact, when money is issued by a public-sector entity, the associated income should accrue to the entity’s owners: the citizens. When, on the other hand, money is issued by a privately owned central bank, the income should accrue to the central bank’s private owners. If the income is not distributed to the owners, it should go into retained earnings and become equity. This argument is consistent with that articulated by Archer and Moser-Boehm (2013).

The assimilation of money to equity requires moving beyond the distinction between equity and liabilities, as discussed in Section 2. A correct application of the IFRS recognizes that the money that is accepted as legal tender is *not* a financial instrument for the holder and therefore it *cannot* be debt for the issuer.

International Accounting Standard (IAS) 32 defines a “financial instrument” as “a contract that gives rise to a financial asset of one entity and a financial liability or equity instrument of another entity,” and defines an “equity instrument” as “any contract that evidences a residual interest in the assets of an entity after deducting all of its liabilities” (par. 11). Under these definitions, legal tender money is neither “credit” for its holders nor “debt” for its issuers. It is instead net wealth of the holders and net worth (equity) of the issuers.

Money accounted as the issuer’s equity implies ownership rights. These rights do not give money holders possession over the entity issuing the money (as shares giving investors ownership of a company or residual claims on the company’s net assets). Rather, they are the same as those acquired by consumers purchasing goods by firms, since selling a commodity that grants specific utility to consumers is not conceptually dissimilar from selling an instrument that grants its acquires a general type of utility – that of settling financial obligations.<sup>4</sup> They consist of claims on shares of national wealth, which money holders may exercise at any time.<sup>5</sup> Those

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<sup>3</sup> Income, in the most general meaning of enhancing equity, may take the form of capital income or revenue income. The former does not relate to running a business, while the latter arises from running business activities (Maheshwari, 2013).

<sup>4</sup> However, the similarity between money and goods in providing utility to holders and consumers, respectively, does not eliminate the unique features of money, such as its zero (or negligible) elasticity of production and its zero (or negligible) elasticity of substitution (Davidson, 1972).

<sup>5</sup> An explanation is due on the use of the word “claim” in this context. If, in an economy, people conventionally agree to sell their labour services, products, and assets to one another in exchange for an intrinsically valueless object called “money”, then, in force of that very same conventional agreement, people believe such money to give their holders a claim to purchase labour services, products, or assets in exchange for it. Now, such claim is not enforced by any law, it does not bind anybody to engage unwillingly in the exchange process, nor is it a claim pending upon any specific individual. Rather, it is a generalized claim on the economy at large (and all of its agents) – a claim that gives money holders the right to exchange their money holdings in transactions that take place at terms and conditions to be mutually and freely agreed between the transacting parties. In other words, saying that money is a claim on society’s wealth does not mean that people are forced to sell their values in exchange for money. It means though that people must accept money if they want to sell their values. The issue at stake here is one of “prevalence of substance over form”, which is typically encountered in the accounting practice. Money is not a legal, or formal, claim toward somebody, but a substantial claim over a

who receive these claims acquire purchasing power on national wealth, and those issuing these claims get in exchange a form of gross income of equal nominal value. The income calculated as the difference between the gross revenue from money issuance and the cost of producing money (i.e., seigniorage) is appropriated by the entity issuing the money.

*Implications* Several implications follow from the proposed approach. First, income from seigniorage is systematically concealed and seigniorage is not allocated to the income statement (where it naturally belongs), while it is recorded on the balance sheet under debt liabilities, thus originating outright false accounting.

Second, “primary” seigniorage, that is, the income that derives from the creation of money *ex nihilo* and by fiat decision should be distinguished from “secondary” seigniorage, which derives from the interest income received on the money that is issued and loaned. The state does not receive any secondary seigniorage from coins (they are not loaned), while central banks receive seigniorage from both banknotes and reserve issuances but account only for the former, not for the latter. The distinction between primary and secondary seigniorage will be the subject of empirical estimations in Section 4.

Third, central banks with the power to issue the national currency may “create” their own capital, and they can do so at any time they need to. In other words, to the extent that a central bank retains the power to issue money, it can never find itself in a position of having to request for recapitalization by the government.<sup>6</sup> It follows that central bank independence may never be threatened by problems of under-capitalization. It follows also that the “optimality” of central bank capital can be defined only in relation to the monetary policy objectives that the central bank is mandated to pursue.

Fourth, the implications above identify with clarity who would provide the ultimate backstop in a crisis situation. Discussions around the backstop function often entail a (rather paradoxical) vicious-circle argument whereby, when at stake is the risk of a government defaulting on its own debt obligations, the monetization of debt through money creation is usually considered - at least in principle - as providing the last-resort remedy to avoid default: the central bank would be the backstop in this case. On the other hand, when at stake is the risk of a central bank running into financial losses, the government is invoked as the last-resort provider of the extra capital needed to rebuild the central bank’s equity position: in this case, the backstop is

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nominally equivalent share of society’s wealth. Should people not take it as such, they would not accept it in the exchange process and money would be soon worth nothing.

<sup>6</sup> The power to create one’s own capital is perhaps the most vivid example of what economists refer to as a “free lunch”, and it derives from the power to issue fiat money. The free lunch from money issuance may be socially beneficial, if the newly created purchasing power is employed to mobilize unutilized resources and to produce new output, or it may resolve only into higher prices with no net social benefits. In this case, however, the money issuer still enjoys a free lunch in that it holds a claim on real resources that it would not hold, absent that power. The whole pie would be smaller for each eater (due to the effect on prices), but a share of it would go to the one eater who has not contributed to its preparation.

the government. But the two options can't both be true. The true backstop can only be the entity that holds the power to issue the currency.<sup>7</sup>

Fifth, under the accounting practices currently adopted by national governments and central banks, seigniorage is largely under-appreciated. It will be necessary to identify and to estimate such seigniorage, the share of seigniorage that is returned to its legitimate "owners" (the citizens), and its effects on economic activity as well as on the economy's incentive structure and the distribution of national wealth across society. Moreover, for public finance purposes, the application of correct financial accounting principles and standards would allow to "clean up" the fiscal budgets and central bank balance sheets from the false practice of associating legal tender to "debt."

Finally, an argument could be made whereby the government should be entitled to receiving back the seigniorage extracted by the central bank from the economy (after having made provisions for covering the central bank's running and capital costs). For the reasons discussed above, this would in no way weaken the financial position of the central bank, which would always be able to operate the country's monetary policy agenda based on its underlying objectives and with not concern for its own level of equity. The use of seigniorage income by the government would be a fiscal policy decision that should be subject to the country's political process, taking into consideration distributional and macroeconomic factors, but under the principle that seigniorage income ultimately originates from, and belongs to, the wealth of the country's citizens.

### 3.2 Commercial Bank Money

*Commercial bank money and central bank reserves* After long being a tenet of post-Keynesian theories of money,<sup>8</sup> even mainstream economics has recognized that commercial banks are not

<sup>7</sup> Buiter (2008) argues that the taxpayer, through the treasury, is the ultimate and only guarantor of central bank solvency. In fact, based on the argument above, Buiter's assertion holds in the deeper and more general sense that the backstop function can only work if there are real resources available in the economy that can be extracted from their owners through either explicit taxation or the implicit (inflation) tax inherent in money creation. It should be noted, however, that even before getting to the point where real resources would be exhausted, in actual circumstances a confidence crisis in a country economy might be such that people would want to dump *both* government debt and cash for foreign securities, thereby neutralizing the ultimate backstop role of the central bank. Under such circumstances, the backstop function could only be provided by an external actor.

<sup>8</sup> See, for instance, Moore (1979, 1983) and the literature on monetary circuit theory. As this is too vast to be cited here and do justice to its many contributors, we refer only to the work by Augusto Graziani (2003), one of the theory's most authoritative exponents. In fact, a survey into the history of economic ideas reveals important antecedents. The process by which commercial banks create money when they issue new credit was central to the thinking of prominent figures such as Knut Wicksell, Friedrich Hayek, Irving Fischer, John Maynard Keynes and Joseph Schumpeter and was an integral aspect of theories on banking and money at the beginning of the 20th century (Turner 2013, Werner 2014).

simple intermediaries of already existing money – they create their own money by issuing liabilities in the form of demand deposits (McLeay et al., 2014).<sup>9</sup>

In fact, in contemporary economies the largest bulk of money is created by commercial banks (Ryan-Collins *et al.* , 2011).

If banks create money by lending or selling deposits, they do not need to raise deposits in order to lend or to sell deposits (Werner, 2014).<sup>10</sup> Still, they must avail themselves of the cash and reserves necessary to guarantee cash withdrawals from clients and to settle obligations to other banks emanating from client instructions to mobilize deposits to make payments and transfers.

The relevant payment orders are only those between clients of different banks, since the settlement of payments between clients of the same bank (“on us” payments) does not require the use of reserves and takes place simply by debiting and crediting accounts held on the books of that bank. For cash withdrawals and interbank payments, every bank must determine the optimal amount of cash and reserves needed to cover deposits. These consist of: i) cash reserves and reserves deposited with the central bank; ii) reserves from settlement of incoming payments from other banks; iii) borrowings from the interbank market; iv) borrowings from the central bank; v) immediate liquidation of unencumbered assets in the balance sheet, and vi) new deposits of cash from old and new clients.<sup>11</sup>

*Accounting treatment* Commercial bank money constitutes a *debt* liability for deposit issuing banks, since they are under obligation to convert deposits into cash on demand from their clients and to settle payments in central bank reserves at the time required by payment system settlement rules.

However, in a fractional reserve regime banks hold only a fraction of reserves against their total deposit liabilities. The amounts of reserves they actually use for settling interbank obligations are only a fraction of the total transactions settled.

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<sup>9</sup> In a post titled Central Bankers: ‘We’re all Post-Keynesians now’, Jesse Frederik suggests that central bankers may have grasped the reality of commercial bank money creation somewhat earlier than academics, who in their textbooks still to this day continue to subscribe to the conventional “money multiplier” story. See also the related post Who is right? Krugman or Keen or / and 9 Central Bank economists?). Interestingly, among central banker, Sir Mervyn King, former Governor of the Bank of England, addressing a conference of businesspeople once recognized that, “When banks extend loans to their customers, they create money by crediting their customers’ accounts.” (Speech to the South Wales Chamber of Commerce at The Millenium Centre, Cardiff on 23 October 2012).

<sup>10</sup> Banks create money by lending or selling deposits. Lending deposits features very close analogies to selling deposits. As banks issue deposits to clients in exchange for money, banks become owners of the money received and acquire the rights to use it as they wish (subject to existing laws and regulations). Even if the banks are constrained in the use of the money – such as, for instance, in the case of regulation prescribing the types of assets to be held – they (not the depositors) are the owners of the purchased assets and they (not the depositors) are the owners of the income generated by the purchased assets.

<sup>11</sup> The new non-cash deposits from clients can only consist of deposits transferred from other banks, which fall under item ii) above.

The more limited is the use of cash in the economy, and the larger are the economies of scale in the use of reserves (as permitted by payment system rules and clients' non-simultaneous mobilization of deposits), the lower is the volume of reserves that banks need to back up the issuance of new de-posits.<sup>12</sup>

Payment system rules affect the use of reserves via two channels: the settlement modality (that is, netting or gross settlement) and the technology adopted. Modern technologies introduce elements of netting into gross settlement processes and increase the velocity of circulation of reserves, thereby allowing banks to economize on the use of reserves for any given volume and value of payments settled.

In the hypothetical case of a fully consolidated banking system in a cashless economy where all agent accounts sit with only one bank, all payments and transfers would be "on us" for the bank. The bank would need no reserves for settling transactions and would be under no debt obligation to its clients. It might create all the money that the economy could absorb without holding reserves, and its money would have the same power as legal money in settling all debts.

In real-world economies, however, there are multiple banks whose payment activities generate interbank settlement obligations. Yet, the fractional reserve regime and the economies of scale allowed both by payment system rules and by depositors' non-simultaneous mobilization of deposits reduce the volume of reserves needed by the banks to back their debts. Under increasing scale economies, banks can create more liabilities (by lending or selling deposits) with decreasing reserve margins for coverage. From the hypothetical case above and from this discussion, it follows that, all else equal, a more consolidated banking system affords lower coverage of its liabilities (and at lower cost) than a less concentrated one.

More generally, absent adverse economic or market contingencies inducing depositors to convert deposits into cash or to transfer them across banks, the liabilities represented by deposits *only partly* constitute debt liabilities of the issuing bank, which as such require cash and reserve coverage. The remaining part of the liabilities are a source of income for the issuing bank income that derives from the bank's power to create money. In accounting terms, to the extent that this income is undistributed, it is equivalent to *equity*. Total demand deposits, therefore, consist of "debt-deposits" and "equity-deposits."

The double nature of deposits is *stochastic* in as much as, at issuance, every deposit unit can be either a debt-deposit (if, with a certain probability the issuing bank receives requests for cash conversion or interbank settlement) or an equity-deposit (with complementary probability). Faced with such stochastic double nature of its money, a commercial bank finds it convenient to provision the deposit unit issued with an amount of reserves that equals only the expected value of the associated debt event (possibly corrected by a margin of uncertainty), rather than the full value of the deposit unit issued.

<sup>12</sup> For the use of cash, in cases where the monetary authority declares deposit inconvertibility and prohibits deposit transfers across borders, bank money effectively replicates central bank money, whereby reserves cannot circulate out of the central bank's books: any single commercial bank may dispossess itself of its own reserves (if some other banks demand them), but all of them cannot altogether do so since reserves once created remain outstanding until they are paid or sold back to the central bank.

“Stochastic” refers to the fact that – ex ante – a bank creating one unit of deposit expects (probabilistically) that only a share of that unit will translate into debt, while the remaining share (still probabilistically) will not be subject to requests for conversion into cash or reserves. The share of debt-deposits (or equity-deposit as its complement) is a stochastic variable that is influenced by behavioural and institutional factors (for example, cash usage habits, payment system rules) as well as by contingent events. For example, in times of market stress, the share of debt-deposits tend to increase, while they tend to be lower when there is strong trust in the economy and the banking system in particular. Policy and structural factors that strengthen such trust (for example, the elasticity with which the central bank provides liquidity to the system when needed or a deposit insurance mechanism) increase the share of equity-deposits.

This argument is evident when applied to the whole banking system, but it also holds for each individual bank albeit to different extents depending on the size of each bank for a given payment settlement system and cash usage<sup>13</sup> From the discussion so far it follows that, all else being equal, the stochastic share of debt-deposits for a small bank are greater than for a larger bank. Vice versa, the larger is the bank, the greater is the share of equity contained in its deposit liabilities.

*Consistency with international accounting standards* The stochastic double nature of commercial bank money is consistent with the definition of liability provided by the new Framework under IASB (2018), whereby, “a liability is a present obligation of the entity to transfer an economic resource as a result of past events”<sup>14</sup> and “Financial reports represent economic phenomena in words and number. To be useful, financial information must not only represent relevant phenomena, but it must also represent the substance of the phenomena that it purports to represent. In many circumstances, the substance of an economic phenomenon and its legal form are the same. If they are not the same, providing information only about the legal form would not faithfully represent the economic phenomenon.”<sup>15</sup>

In light of these definitions, demand deposits are a *hybrid* instrument - partly debt and partly revenue. The debt part relates to the share of deposits that will (likely) be converted into banknotes on demand or into reserve for payment settlement purposes and reflects the “substance” of the obligation underlying the deposit contract. The revenue part, on the other hand, relates to the share of deposits that will (likely) never be converted into banknotes or reserves, and reflects the mere “legal form” underlying the deposit contract. Once accumulated, this revenue becomes equity.

Now, since there is no accounting standards governing hybrid revenue-liability instruments explicitly, IAS 32 applies (in force of the analogy stated in IAS 8) and provides that, in the context of a hybrid liability instrument, the debt component must be separated from the equity

<sup>13</sup> Size here refers to the volume of payment transactions that the bank intermediates relative to the total payment transactions in the system.

<sup>14</sup> Section 4.26 of the Framework.

<sup>15</sup> Section 2.12. of the Framework.

one.<sup>16</sup> From operating such separation follows that, once the debt component is identified, the residual left is the equity component.<sup>17</sup> In the case of deposits, the share of deposits that (most probably) will not translate into debt liabilities represent retained earnings (that is, equity capital).

The application of IAS 32 is a textbook case. It implies that the financial statement of the issuing bank should report among debts only the share of deposits that give origin to a substantial obligation to transfer economic resources, while the residual share should be reported in the income statement as revenue. Moreover, since the share of profits attributable to this revenue is undistributed, it add to the bank's equity.

To support the validity of the approach here proposed, consider IAS 37 (on risk provisioning, charges and contingent liabilities).<sup>18</sup> This standard considers as debt all commitments that fall under the Framework's definition of "liability," that is, those that generate outflows of economic resources with a probability greater than 0.5. Below such threshold, the liability is a *contingent liability* and must only be reported in the notes to the financial statements.

The implication is inescapable: the existence of formal claims is not alone sufficient for a liability to be considered as debt; the essential requisite is the probable outflows of economic resources. The probability is not *per se* relevant, yet it is so in this case since it allows for an assessment of the faithful representation of the transactions involved.<sup>19</sup> In the case of commercial bank money, the share of deposits that are not debt liabilities must be regarded as revenue, and since such revenue is not reported in the income statement, it constitutes retained earnings (or equity).

*Implications* In fractional reserve regimes, commercial bank money (that is, demand deposits) has a double nature. This originates from the power of banks to create a form of money that only partly has the nature of debt.

Some critical implications follow. The first is that a relevant share of deposits that banks report in their financial statements as "debt toward clients" generate revenues that are analogous to

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<sup>16</sup> Specifically, IAS 8 (Sections 10-11) requires that, "In the absence of an IFRS that specifically applies to a transaction, other event or condition, . . . management shall refer to, and consider the applicability of, the following sources in descending order: (a) the requirements in IFRSs dealing with similar and related issues; and (b) the definitions, recognition criteria and measurement concepts for assets, liabilities, income and expenses in the Framework."

<sup>17</sup> See IAS 32, Sections 28 et.ss. It is noteworthy that, in the case ruled by the quoted standard, the hybrid instrument has the double nature of 'liabilities-capital' and not of "liabilities-revenue: "; however, both capital and retained earnings belong to equity. Briefly, equity can be shared into at least two major components: capital and other ownership's contributions, on the one hand, and retained earnings on the other. IAS 32 provides regulation for splitting hybrid instruments between a part attributable to liabilities and a part attributable to equity. Based on the definitions of the Framework, once the component recognizable as debt liability is identified, the residual component is attributed to equity.

<sup>18</sup> See IAS 37, Sections 12-13, where the fundamental distinction is drawn between the adjective "probable" for the debt liabilities and the adjective "possible" for contingent liabilities to be reported in the notes to the financial statements.

<sup>19</sup> See IASB (2018), Section 5.17.



the seigniorage rents extracted by the state and the central bank through the issuance of legal money (coins, banknotes and central bank reserves). This, in turn, bears implications for the way banks' capital is calculated. Critical for this calculation is the probability factor discussed above, which characterizes each bank individually, depending importantly on its size (relative to the other banks of the market(s) where it operates) and its role in the payment system. Different calculations of bank capital would impact on each bank's potential to extend loans and should lead policy authorities to focus on the optimal liquidity of bank capital – an issue we are not going to pursue further here.

The second implication is that much as demand deposits are hybrid instruments, commercial banks are hybrid institutions, too: as issuers of debt-deposits, when they lend money they act as pure intermediaries; as issuer of equity-deposits, they are money creators. For these reasons, and for the reasons discussed above, smaller banks tend to fall within the former category, whereas larger banks belong more to the latter. Also, and importantly, while the income earned on debt-deposits originates from intermediation, the income from equity-deposits constitutes seigniorage. This distinction will be considered in our estimation procedures in Section 4. Commercial bank seigniorage represents a structural element of subtraction of net real resources from the economy, with potentially contractionary effects on profits and/or wages, distributional consequences, and frictions between capital and labour – all effects that should be studied carefully. Policy considerations should be given to mechanisms that induce banks to re-inject their seigniorage income into the economy, or fiscal measures could be considered to redistribute commercial bank seigniorage across the society. Alternatively, policies could be designed to reduce seigniorage, say, by increasing banking sector competition or by limiting the average size of banks.

Another implication of the Accounting View developed above, which might become relevant especially considering the fast rise of private-sector digital currencies worldwide, is the accounting nature of these currencies. In a recent official report, the Committee on Payments and Market Infrastructures – the international standards setter the international standard setter for payment systems – states several times that such currencies are not a liability of any individual or any institution (CPMI, 2015), whereas a digital currency issued by a central bank would be a central bank's liabilities (CPMI, 2018) – an apparent inconsistency. The Accounting View resolves such inconsistency clarifying that in both cases the currency represents equity capital of the issuing entity. The application of such conclusion would greatly assist national monetary and financial authorities in shaping transparent regulations in the area of digital currencies.

#### 4 Empirical estimates

The empirical estimates of the various types of seigniorage discussed in Section 3 have been based on observations from the UK economy during the 2007-2016 period. The UK was chosen for ease of data availability and in consideration of the recent study covering the UK by Bjerg et

al. and Macfarlane et al. . Data were extracted from databases of the Bank of England, the UK Royal Mint, and the Federal Reserve Bank of St. Louis. Other data were taken from the Bank of England accounts. In order to parameterize primary and secondary seigniorage to relatable economic variables, the tables below report stock values are reported in the tables below as a ratio to public debt, on a year-to-year basis, and flow values as a ratio to tax revenues (see the Appendix for details on the methodology adopted).

Concerning commercial bank primary seigniorage, two different estimation procedures were followed. One is a flow-estimation built on the assumption that agents know with certainty the share of demand deposits that will be converted into cash and central bank reserves. The other procedure provides a stock-estimation and is based on the aforementioned probabilistic approach and the related belief that the share of demand deposits that will be converted into cash or reserves is known only with some probability. The stock-estimation is expressed as a ratio to the public debt, while the flow-estimation is expressed as a ratio to tax revenues.

Table 1 shows the stock values of the types of money considered in this study, that is, cash, central bank reserves, demand deposits and Commercial Bank Primary Seigniorage (equity-deposits). The average value of cash calculated across the observation period is 5.04%, while the average value of central bank reserves and demand deposits is 13.30% and 97.18%, respectively. The cash aggregate decreased progressively from 2007 to 2014, and then increased in the following two years. Central bank reserves increased from 2007 to 2010, decreased in 2011, and then increased progressively until 2016. Finally, demand deposits decreased from 2007 to 2012, and then increased from 2013 to 2016. Commercial Bank Primary Seigniorage, as equity deposits, represents 68.58% of the public debt (average value).

Table 2 shows the primary seigniorage estimated on the monetary aggregates above. Primary Seigniorage on Coins has an average value of 0.02%, while Primary Seigniorage on Notes is 0.55%. The highest average values are those of Primary Seigniorage on Central Bank Reserves (5.74%) and Commercial Bank Primary Seigniorage (7.66%). Primary Seigniorage on Coins does not seem to have a regular trend, and Primary Seigniorage on Central Bank Reserves changes considerably also as a consequence of the Quantitative Easing operations undertaken by the Bank of England in response to the crisis. Commercial Bank Primary Seigniorage, too, shows different values from year to year, with the highest being recorded at period end: 15.76% (2014), 12.37% (2015) and 20.98% (2016).

Table 3 shows the estimates of secondary seigniorage. The first column shows the average values calculated over the period, and the second column shows the values as a ratio to tax revenues. Both the Secondary Seigniorage on Notes as well as the Secondary Seigniorage on Central Bank Reserves tend to decrease over the period considered (the former is 0.33% in 2007 and 0.08% in 2016, and the latter is 0.02% in 2007 and 0.01% in 2016). On the other hand, Secondary Commercial Bank Seigniorage increase from 1.46% in 2007 to considerably high values at period end (4.25% in 2014 and 2.39% in 2015).

These estimates show that, when using correct accounting principles, seigniorage – in particular that extracted by commercial banks – is a quantitatively relevant phenomenon. Macfarlane

**Table 1** Money stocks (2007-2016)

<b>Stock</b>	<b>Average Value</b> (£ bn)	Average value (% of UK Public Debt)
Cash (Coins and Notes)	61.5	5.04
Central Bank Reserves	190.9	13.3
Demand Deposits	1,186.9	97.18
Commercial Bank Primary Seigniorage (equity deposits)	837.59	68.58

**Table 2** Primary Seigniorage (2007-2016)

<b>Seigniorage</b>	<b>Average Value</b> (£ bn)	<b>Average value</b> (% of UK Tax Revenues)
Primary Seigniorage on Coins	0.09	0.02
Primary Seigniorage on Notes	3.0	0.55
Primary Seigniorage on Central Bank Reserves	30.6	5.74
Commercial Bank Primary Seigniorage	44.7	7.66

**Table 3** Secondary seigniorage (2007-2016)

<b>Seigniorage</b>	<b>Average Value</b> (£ bn)	<b>Average value</b> (% of UK Tax Revenues)
Secondary Seigniorage on Notes	1.1	0.2
Secondary Seigniorage on Central Bank Reserves	0.1	0.02
Commercial Bank Secondary Seigniorage	14.2	2.62

et al. come to similar conclusions. Yet our results differ from theirs, due to the different theoretical understanding of demand deposits, and most notably their hybrid (double) nature discussed in Section 3,B: first of all, they disregard the primary seigniorage deriving from equity-deposits; second, since they do not distinguish between debt-deposits and equity-deposits, they use total

deposits as the base for calculating secondary seigniorage and thus over-estimate it. According to their results, UK annual average commercial bank seigniorage averages £23.3 billion (calculated over 1998-2016 period). By applying net interest margins to equity-deposits only, our study reports a much lower average of £14.2 billion (calculated over 2007-2016).

## 5 Conclusion

Based on the correct application of international accounting principles, this study has argued that state monies – in the form of legal tender and central bank money – are not debt, and that in a fractional reserve regime only a share of commercial bank money can be regarded as debt. Proceeding separately for the two broad types of money, the study has determined the correct way to account for them in the financial statements of the issuing institutions, clarifying what the different accounting treatment implies for a correct understanding of the various forms of money, and laying the foundations for what we have labeled the “Accounting View” of Money. Importantly, this new view throws light into such issues as the nature of central bank capital, the nature of commercial bank money as hybrid instruments, the nature of commercial banks as hybrid institutions (partly pure intermediaries and partly money creators), and the apparent inconsistency on the accounting nature of private-sector digital currencies.

Furthermore, drawing on the implications of the new approach, the study has derived new measurements of the seigniorage extracted by the state, the central bank, and commercial banks, respectively, and has applied them to the UK (for which previous estimates are available). The results have revealed that seigniorage, in particular that extracted by the commercial banking sector, is a quantitatively relevant phenomenon that deserves further research.

More broadly, the study has aimed to resolve this apparent inconsistency between the formal rules of reporting money liabilities in the financial statements of the issuing institutions, on the one hand, and the economic substance of the money liabilities to be reported in the statements, on the other. Resolving this inconsistency requires a deep interaction between Accounting and Economics the underlying intent of this study. The general lack of communication between the two disciplines has caused the inconsistency to persist unaddressed for decades.

### Appendix: Methodological Notes

This Appendix describes the calculation procedures adopted to estimate the various types of seigniorage discussed in this study. The data used and the sources from where data were drawn. The estimates refer to the 2007-2016 period, except for those that relate to the Commercial Bank Secondary Seigniorage, for which the latest data available is for year 2015.

In order to parameterize primary and secondary seigniorage to relatable economic (stock and flow) variables, they have been expressed as ratios to public debt and tax revenues, respectively. The data on public debt were collected from the “*UK government debt and deficit: September 2017*” Statistical Bulletin, issued by the UK Office for National Statistics. The

data on tax revenues were collected from the "UK Tax Revenues" database of the OECD (<https://stats.oecd.org/Index.aspx?DataSetCode=REVGBR>).

### Primary Seigniorage on Coins

The total value of coins issued per year were derived from the yearly quantity of coins issued per each of the 8 coin denominations (from £2 to 1p) as reported by the UK Royal Mint (<https://www.royalmint.com/discover/uk-coins/circulation-coin-mintage-figures/two-pounds-to-20p-issued/>; <https://www.royalmint.com/discover/uk-coins/circulation-coin-mintage-figures/10p-to-half-penny-issued/>). Since the Royal Mint does not reveal information on the cost of production of coins, for purpose of estimate this was assumed to be half the value of the coins issued.

### Primary Seigniorage on Notes

Primary seigniorage on banknotes stems from the issue value of new notes in any given year net of their production cost, and it is calculated as the difference between the stock of notes in circulation in any two consecutive years, net of the cost of production of the new notes.

The following items have been used for the purpose of this calculation:

1. Stock of notes in circulation: these are reported among the liabilities in the Bank of England Issue Department statement of balances
2. Production costs and other expenses: these are reported in the Bank of England Issue Department income statements accounts.

Thus,

$$\text{Primary Seigniorage on Notes}_t = \Delta(\text{Notes in circulation})_{t,t-1} - \text{Issue Department expenses}_t$$

### Secondary Seigniorage on Notes

This was taken directly from the Bank of England Issue Department income statement accounts, where income and profits arising from the assets corresponding to the notes in circulation are reported. Reference is made to the two accounting items "Income from securities of, or guaranteed by, the British Government" and "Income from other assets including those acquired under reverse repurchase agreements". These incomes and profits are returned to HM Treasury. Hence:

$$\text{Secondary Seigniorage on Notes} =$$

*Income from securities of, or guaranteed by, the British Government +  
Income from other assets including those acquired under reverse repurchase agreements*

### Primary Seigniorage on Central Bank Reserves

This is calculated as the yearly change in central bank reserves,

$$\text{Primary Seigniorage on Central Bank Reserves}_t = RES_t - RES_{t-1}$$

Data on reserves (RES) were drawn from Bank of England statistical database (code LPMBL22).

### Secondary Seigniorage on Central Bank Reserves

Since 2006, the Bank of England has paid interest to commercial banks on their holding of central bank reserves, which is equal to the rate of interest Bank of England earns on the assets that correspond to the reserves. Consequently, the creation of new central bank reserves turns out to be revenue-neutral, since there is no seigniorage income earned on them.

On the other hand, the so-called Cash Ratio Deposits (CRDs) are non-interest-bearing deposits lodged with the Bank of England by eligible institutions (i.e. banks and building societies), who have reported average eligible liabilities (ELs) in excess of £600 million over a six-month calculation period. The level of each institution's CRDs is calculated twice yearly (in May and November) at 0.18% of average ELs in excess of £600 million over the previous six end-calendar months. These reserves generate seigniorage, since Bank of England can invest these funds in interest yielding assets (mainly government bonds) and the interest earned is used to fund the costs of its monetary policy and financial stability operations. Under the Bank of England Act 1998, the percentage used in calculating the Cash Ratio Deposits is set by HM Treasury, having regard to the financial needs of the Bank and subject to the approval of both Houses of Parliament. If the Bank of England did not impose this requirement, the government would have to fund the cost of monetary policy and financial stability operations in some other way (for instance, via taxation) (Macfarlane et al.).

The data on CRDs were drawn from Bank of England Financial Statements Notes to the Banking Department Financial Statements. The average return on CRD investments were taken from the HM Treasury Reviews of the Cash Ratio Deposit scheme issued in 2013 and 2018. Average investment yield on CRD deposits over the period March 2008-February 2013 was 4.25 per cent, while average annual investment yield on CRD deposits over the period March 2013- February 2018 was 2.7 per cent. Considering that CRDs are zero-cost reserves, as Bank of England does not pay any interest on them to commercial banks, Secondary Seigniorage on Central Bank Reserves is calculated as:

$$\begin{aligned} \text{Secondary Seigniorage on Central Bank Reserves}_t = \\ \mathbf{CRDs}_t \times \text{Average return on CRD investments} \end{aligned}$$

### Commercial Bank Primary Seigniorage

In line with the discussion in Section 3.B, this is calculated only on equity-deposits. Two different estimation procedures were adopted. One is based on the assumption that the share of demand deposits that will be converted into cash and central bank reserves is known with certainty. Accordingly, equity-deposits are calculated simply by subtracting reserves and notes and coins from the total demand deposits aggregate. Considering that notes and coins deposited (and therefore not in circulation) are not part of M1, they have to be subtracted twice. As seigniorage is calculated in flow terms,

$$\text{Commercial Bank Primary Seigniorage}_t = \Delta[M1 - (2M0) - RES]_{t,t-1}$$

where:

1. **M0**: currency in circulation (notes and coins)
2. **M1**: M0 + demand deposits
3. **RES**: reserves held at the central bank.

The second estimation procedure reflects the probabilistic approach discussed in Section 3.B, whereby the share of demand deposits that will be converted into cash or reserves (debt-deposits) is known only with some probability. Here, this probability is calculated as

$$\text{Probability of debt-deposits} = (M0 + RES)/\text{demand deposits}$$

where the value of the ratio on the RHS of the equation is the average of the ratio values observed during the given period. This way of calculating the probability is justified on the ground that the observed data on the money aggregates reveal the agent preferences between cash and demand deposits as well as the commercial banks' demand for central bank reserves.<sup>20</sup> Based on past observations and looking forward, therefore, the ratio on the RHS of the equation

<sup>20</sup> The latter, however, is subject to identification problems, since central banks reserves are supply-driven and banks, collectively, are bound to hold any amount of reserves that the central bank supplies. Statistics on reserves, therefore, can hardly be used to proxy commercial banks' demand for them. This is even more evident in times of Quantitative Easing, where commercial banks had simply to hold all excess reserves deliberately created by the central banks for policy purposes. Yet, since when estimating equity-deposits a good practice would require to be conservative, any over-estimation of commercial banks' demand for reserves would ensure extra conservatism in the estimation procedures.

above should indicate how much of total demand deposits should be expected to be converted into cash and reserves each year. Obviously,

$$\textit{Probability of equity-deposits} = 1 - \textit{probability of debt-deposits}.$$

For prudential purposes, this value can be corrected for uncertainty by subtracting from it the variability of the  $(M0 + RES)/\textit{demand deposit}$  series,

$$\textit{Corrected probability of equity-deposits} = (1 - \textit{probability of debt-deposits}) - \sigma$$

and, finally,

$$\begin{aligned} \textit{Commercial Bank Primary Seigniorage}_t = \\ \textit{Demands Deposits}_t \times \textit{Corrected probability of equity-deposits} \end{aligned}$$

To identify the monetary aggregates, the following Bank of England data were used:

1. Notes and coins: monthly average amount outstanding of total sterling notes and coins in circulation, excluding backing assets for commercial banknote issue in Scotland and Northern Ireland total not seasonally adjusted. Source: Bank of England Statistical database (code LPMAVAA).
2. Central Bank Reserves: monthly average of amounts outstanding (on Wednesdays) of Bank of England Banking Department sterling reserves balance liabilities (in sterling millions) not seasonally adjusted. Source: Bank of England statistical database (code LPMBL22).
3. Demand deposits: quarterly amounts outstanding of monetary financial institutions' sterling and all foreign currency M1 liabilities to private and public sectors not seasonally adjusted (UK estimates of EMU aggregate). Source: Bank of England Statistical database (code LPQVWYE).

For each series, all data were averaged over each year.

#### Commercial Bank Secondary Seigniorage

Defined as the net retained earnings originated from equity-deposits, Commercial Bank Secondary Seigniorage was estimated based on the two estimations of equity-deposits derived above. Thus,

$$\textit{Commercial Bank Secondary Seigniorage}_t = [M1 - (2M0) - RES]_t \times \textit{net interest margin}$$

and



$$\text{Commercial Bank Secondary Seigniorage}_t =$$

$$(\text{Demands Deposits}_t \times \text{Corrected probability of equity-deposits}) \times \text{net interest margin}$$

Net interest margin is the difference between the interest income earned and the interest paid by a bank or financial institution relative to its interest-earning assets. Data concerning net interest margin were collected from the database of Federal Reserve Bank of St. Louis (<https://fred.stlouisfed.org/series/DDEI01GBA156NWDB>).

The results from the two estimation procedures are substantially converging.

A final notation. As discussed in Section 3.B, the estimation of Commercial Bank Secondary Seigniorage should take into consideration the explicit and implicit costs associated with commercial bank borrowing from the central bank for payment settlement purposes. The former derive from the interest rates charged on overnight lending operations, while the latter derives from the opportunity cost of immobilizing resources as collateral to be pledged with the central bank for intra-day borrowing. Due to data limitation purposes, these cost factors have not been included in this study's estimation procedures. However, as also noted by Macfarlane et al. , during the period observed, especially after 2009, the massive increase in the quantity of reserves in the banking system has reduced dramatically the borrowing activity of commercial banks.

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# Working Papers

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## From Cash to Accrual Accounting: The seminal case of the Sicilian Regional Public Bodies

Massimo Costa · Francesca Cimò

**Sommario** The Italian public sector has been traditionally characterised by a cash based and compliance oriented governmental accounting, principally aimed at supporting the budgetary control by the legislative body. Over the last few decades, however, a new movement has been spreading around the world, casting doubt on the potentialities and advantages of the traditional accounting system in favour of an accrual basis one. This paper traces the progressive introduction of a complete accrual accounting by the Sicilian Regional public bodies within the context of international and national public management changes pursuing the ultimate goal to improve efficiency, accountability and transparency. After a close examination of the major choices made by a Committee established for this purpose, the work investigates about the need to go beyond a simple accrual basis accounting system especially in a context where concepts like inter-institutional horizon and public value are more and more relevant.

**Keywords** NPM · accrual accounting · chart of accounts · Sicilian Regional public bodies · public value.

**Riassunto** *Il settore pubblico italiano è stato tradizionalmente caratterizzato da una contabilità governativa basata sul contante e sulla conformità, principalmente intesa a sostenere il controllo di bilancio da parte dell'organo legislativo. Negli ultimi decenni, tuttavia, un nuovo*

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*movimento si è diffuso in tutto il mondo, mettendo in dubbio le potenzialità e i vantaggi del sistema contabile tradizionale in favore di una base di competenza. Questo lavoro traccia la progressiva introduzione di una contabilità per competenza completa da parte degli enti pubblici regionali siciliani - nel contesto dei cambiamenti di gestione pubblica internazionali e nazionali - perseguendo l'obiettivo finale di migliorare l'efficienza, la responsabilità e la trasparenza. Dopo un attento esame delle principali scelte fatte da un comitato istituito a tale scopo, il lavoro indaga sulla necessità di andare oltre un sistema contabile di contabilità 'semplice' per competenza, specialmente in un contesto in cui concetti come orizzonte interistituzionale e valore pubblico sono più e più rilevanti.*

*La metodologia della ricerca è di natura qualitativa. Essendo il nucleo di esso un caso di studio, sarà presentato nella sua ricostruzione storica, sottolineando i principali eventi che hanno rilevanza rispetto all'oggetto della nostra ricerca.*

*Per questo motivo, dopo una breve rassegna della letteratura e un focus sui processi italiani riguardanti il NPM, vengono presentate le prove empiriche del caso siciliano. Si basa principalmente su atti normativi, emanati dal corpo legislativo siciliano (l'Assemblea regionale) o dall'organo esecutivo siciliano (il Presidente della Regione o la Giunta regionale di Governo) e, successivamente, sul 'piano dei conti' principale emesso con il pilota esperimento sui Consorzi per la bonifica dei terreni, con il commento di uno dei suoi membri.*

*Alcune brevi osservazioni conclusive concluderanno il lavoro.*

*Qui, il caso di studio degli enti pubblici regionali siciliani sarà analizzato secondo un punto di vista critico. Infatti, sebbene l'introduzione di una contabilità per competenza abbia rappresentato un cambiamento 'epocale', oggi la necessità di un sistema più completo e integrato sta diventando sempre più pressante. In effetti, concetti come 'valore pubblico' suggerirebbero l'introduzione di un quadro contabile in grado di tenere conto di tre campi principali, detti anche 'tre pilastri della sostenibilità': quelli sociali, ambientali e finanziari, rispettivamente. Pertanto, il lavoro vuole rappresentare spunti di riflessione e basi per ulteriori ricerche in futuro.*

***Parole chiave*** NPM - contabilità per competenza completa enti pubblici regionali siciliani - valore pubblico

## 1. Introduction

Over the last decades and on the wave of the NPM-reforms, the Italian public administration has undergone relevant changes addressed to revise the intrinsic faults of the traditional bureaucratic model as do those related to the cash-based traditional accounting system.

The aim of this paper is to outline the process of modernisation of accounting with reference to the Sicilian Regional public bodies experience by sketching a cursory overview of the international as well as the national NPM theoretical background that somehow laid the foundations for its launch. Thus, a methodological approach that goes from a general to a particular perspective has been followed.

In a context characterised by heterogeneity of applications of accrual accounting, the current work intends to analyse the move from cash to accrual accounting in such bodies by trying to respond to the following questions:

- How has the introduction of an accrual basis accounting system occurred?
- What have the major novelties been?
- Can the new delineated accounting system be considered still adequate in the light of the current scenario where such bodies are required to operate?

Although the term New Public Management has developed as summary description of a way of reorganising public sector bodies to bring their management, reporting and accounting approaches closer to (a particular perception of) business methods (Dunleavy and Hood, 1994), the Sicilian case study presents a peculiar interest that would explain the reason behind the choice to study such an issue. Indeed, the introduction of a complete accrual basis system has not occurred in the way of a pure translation of principles and techniques from the business world, as the classical interpretation could suggest, but rather by thinking a system able to keep into account the features belonging to no profit organisations. Moreover, such experience becomes more and more singular if one considers that the Sicilian Regional government has not yet opted for an accrual accounting system.

The methodology of the research is of qualitative nature. The core of it being a case study, it will be presented in its historical reconstruction, underscoring the main events having relevance with respect to the object of our research.

For that reason, after a short literature review, and a focus on Italian processes concerning NPM, the empirical evidence from the Sicilian case is presented. It is based mainly on normative acts, issued by the Sicilian legislative body (the Regional Assembly) or by the Sicilian executive body (the Regional President or the Sicilian Government) and, after, on the main chart of accounts issued with the pilot experiment on the Consortia for Land Reclamation, with the comment on it by one of its members (Costa, 2009).

Some brief concluding remarks will conclude the work. Here, the Sicilian Regional public bodies case study will be analysed according to a critical viewpoint. Indeed, although the introduction of an accrual basis accounting has represented an epochal shift, nowadays the need for a more complete and integrated system is becoming more and more pressing. Indeed, concepts like public value (Moore, 1995) would suggest the introduction of an accounting framework able to keep into account three major fields, also called the three pillars of sustainability: the social, the environmental and the financial ones, respectively. Thus, the work wants to represent food for thought and ground for further research in the future.

## 1. Literature Review

### 2.1 New Public Management: a theoretical framework

Since the early 1980s, a transformative process having an Anglo-American flavour and aimed at improving public sector performance began to take the first steps, laying the foundations for remarkable changes that shortly after would have profoundly affected the way through which public administrations have been traditionally handled by engendering a new culture of performance and quality service delivery.

Before then, it seemed as if managerial matters mainly concerned the private sector and not also the public one. However, one should not come to a conclusion according to which public administrations have neglected managerial issues but instead the above statement should be opportunely framed within a broader administrative and political context that has proclaimed before of a large-scale spread of the NPM movement – the triumph of the Weberian model.

Typical of most continental European countries, Webers bureaucratic model owns the feature of being rule-oriented, meaning that the *res publica* management is based on the observance of legal norms and highly formalised procedures, a model that also had some kind of implications on the *Rechtsstaat* doctrine widespread in the German-speaking countries.

In such a context, a growing tendency to revise the role of public sector entities as well as the overall public service delivery has represented a turning point in history mainly because of the shift from the traditional model – as briefly described above – to a distinct managerial perspective featured by an output and outcome orientation which hopefully would have led to substantial improvements. Central to this shift was a belief that managing public sector organisations is not different from running private sector organisations (Allison, 1983) once it has been observed that the first ones are species of the wider genus *azienda* (Anselmi, 2001). Consequently, a wave of administrative reform processes took place in many countries leading to the recognition of neo-liberal and neo-managerial beliefs in response to the traditional state ideology now blamed for likely being the major cause of inefficiencies recorded in the public sector. Therefore, the needs of a performance-oriented culture, a better allocation and utilisation of public resources, the improvement of managerial accountability, the financial stability (in view of the European integration process and not only) as well as the need to find new market mechanisms to improve the service quality and then the citizen-customer satisfaction, could be considered the major roots, rationales or driving factors underlying what would be later known under the label of New Public Management (Hood, 1991).

Touted by some scholars as an administrative revolution, NPM has found – geographically speaking – fertile ground for diffusion in Anglo-American countries at first and even in many developing countries, although its diffusion seems perhaps slower, and more ethnically characterised, in developed countries having already their own sound public management tradition. Thus, it seems that such a spread has not occurred at the same pace and way in each involved place because of the diversities ascribable to a mixture of factors that – favourably or unfavourably – influenced the public leaders leeway (in implementing reforms) in terms of a high propensity or reluctance to those principles thought for a good and better governance. If so, it would confirm a stereotype according to which some countries have been more prone to the new managerial practices compared to other ones, demonstrating how reform processes are



inevitably path dependent on those factors themselves.

In order to better figure out such point and by dating back to the L. von Bertalanffys general systems theory one may consider that any entity (and then public sector entities, too) can be defined as a dynamic and open system. This means that any entity variously establishes relationships with the reference environmental system thus presenting the building-up and breaking-down of its inner elements and counteracting, at the same time, entropic processes typical of closed systems and self-referential autopoietic systems as argued by the German theorist N. Luhmann (1984).

Precisely, entities can be qualified as selectively open systems since not any change coming from the outside is able to have some kind of influence on themselves. The responsiveness of an organisational system to external impulses/pressures strongly depends on some factors that can encourage or hamper the relationships among systems. Thus, in the specific case of the NPM, factors like the polity features, the traditional style of governance, the public leaders educational background, the administrative apparatus and many others have played a crucial role in gradually or swiftly adopting (or rejecting) new management techniques and practices designed to fundamentally revamp the public sector. Since it is reasonable to suppose that such factors may differ across countries, it is just as reasonable to expect differences in the schemes of adoption and implementation of the NPM ideas.

Basically, the reform roads adopted could be arranged along a continuum at whose extremes national experiences that range from a lower to a higher degree of incisiveness are placed (De Laine, 1998), showing a pattern of divergence and disproving the assumption that NPM took the form of an isomorphic process around the world. By the way, Pollitt and Bouckaert distinguish among four groups of NPM reformers (2004): the maintainers, the modernisers, the marketizers and the minimal state reformers. Countries like the United Kingdom and New Zealand fit the marketizer profile while the Scandinavian countries can be labelled as modernizer reformers because of their greater scepticism towards NPM ideology.

Despite its wide-scale spread, from the very beginning NPM has met some translation problems when its managerial tenets moved from a country to another one, making the comparison a not very straightforward matter due to the presence of language barriers. Such a difficulty has not been the only one because a semantic issue has been detected since its first appearance in Hood's 1991 seminal article, as well. In fact, as Dunleavy et al. state: there is a substantial branch industry in defining how NPM should be conceptualised and how NPM has changed (2006).

Although several attempts at defining NPM have been carried out by many scholars, nowadays a tarnished vision still persists, contributing to qualify it as an umbrella term because of the large collection of definitions and the lack of unanimous consensus about the nature of the movement itself, too. For Lane, it is mainly a contractualist model (Lane, 2000), Knig dubbed it a mixture of management theories, business motivation psychology and neo-liberal economy (Knig, 1997) while Barzelay described NPM by identifying four distinct models characterised by different principles: a contractualist, a managerial, a consumerist and a reformist model,

respectively (Barzelay, 2002). Lastly, Pollitt holds how NPM would offer a kind of shopping basket of different elements to reformers of public administration (2005) not addressed towards the same direction but having the advantage to make the adoption of NPM principles easier and more flexible in systems characterised by a huge level of complexity.

Even if the wide spectrum of definitions and principles potentially embedded within NPM allows managing the administrative reforms with a greater suppleness by public leaders, it is at the same time responsible for tensions arising from its hybrid character (Aucoin, 1990) whenever the centralising tendencies inherent in contractualism collide with the typical features of the management theory.

The awareness of the absence of a generally accepted definition has aroused some doubts about the nature of the movement itself to such an extent that some assumptions began to take shape: at times NPM has been considered just a fad (Pollitt, 1995; Lynn Jr., 1998) rather than a real new paradigm followed by many reform initiatives aimed at a specific goal representing the lowest common denominator, namely to make the public sector more business-like (Ferlie et al., 1996).

Notwithstanding that, the growing literature tried to extrapolate some basic and recurrent elements underlying NPM ideology and forming its elemental pillars. According to Hood, its doctrinal components could be set out as follows:

- hands-on professional management of public organisation;
- explicit standards and measures of performance;
- greater emphasis on output controls;
- shift to disaggregation of units in the public sector;
- shift to greater competition in the public sector;
- stress on private-sector styles of management practice;
- stress on greater discipline and economy in public sector resource use.

Likewise, the journalist Osborne and the ex-city manager Gaebler, in order to conceptualise the new movement or paradigm, summarised NPM factors into the following three major key guidelines (1993):

- re-definition of the boundaries between State and market made possible thanks to the privatisation and the externalisation of many public functions and services;
- re-definition of the macro-structure of the public sector through decentralisation processes from the central to the regional and local governments;

- re-definition of operational rules of the public sector by introducing new principles and managerial practises inspired by those related to the private sector.

The overall package of NPM innovations could be synthesised into three keywords: disaggregation, competition and privatisation denoting a translation of principles, mechanisms and tools from the private sector to the public one. However, the split-side of NPM comes true whenever its implementation takes the form of a pure translation neglecting the fact that public sector entities have their own features that differ from those concerning the private ones. This matter should be taken into account every time the public sector entities aim at espousing a bundle of new tools and administrative doctrines in view of changes.

So far, plentiful amounts of systematic researches and comparative studies have dealt with NPM reforms; surprisingly a dearth of overall evaluations of its effects has been noticed (Peter and Savoie, 1998). In fact, analysing the impact of NPM on aspects such as efficiency, effectiveness and accountability is not an easy task because it is not a well-defined or coherent set of ideas (Wegrich, 2009). In addition, there is much talk about reform, without action but with hypocrisy and double-talk (Brunsson, 1989). Where studies exist, they are generally quite limited and tend to provide frameworks for evaluation, rather than doing the actual evaluation and they tend to be non-quantified (Wollmann, 2003).

Summing up, it is quite hard to unequivocally identify the effects of NPM reforms; the paradox as stated by Pollitt and Bouckaert (2004) is that these reforms do not seem to need results to fuel their forward march. Perhaps, for this issue, a sharp distinction between the deep scientific basis of this approach and the mere ideological support is still required by the scholar community.

On the strength of the theoretical picture drawn emerges how NPM has spread around the world by giving rise to multiple approaches for introducing its principles and measures to keep into account the different environmental contexts where NPM has been introduced. While some scholars support the hypothesis that NPM represents a new paradigm in the traditional Kuhns meaning (1962), other ones hold how its actual innovative feature would lie on the simultaneous consideration of some elements already known and coming from the private sector. Yet, another dispute marks a watershed between two schools of thought that contend the idea of a convergence or divergence in the way NPM has been implemented, respectively.

Lastly, whether NPM-style reforms have been successful is an arduous question that would require considering both major effects and side effects. Undoubtedly, NPM has allowed public administrations to get better results even though some criticisms have concerned matters of cohesion, trust, fragmentation, coordination, control and other ones. In the light of the limits and weaknesses of NPM and to counteract them, other approaches (e.g. the so-called Public Governance) have been gradually introduced into the public sector to meet more and more pressing needs like, for instance, accountability and transparency and implying the adoption of a holistic/systemic view to catch feedbacks and interrelationships among the involved systems.

Even though the doubt if NPM is pass or still alive could suggest a further analysis, the theoretical framework reveals the importance of NPM since it has represented the starting

point of relevant changes for public administrations although recently it has been overpassed or enriched by other new movements or set of ideas. For what concerns the boundaries of this research it is enough to consider, for the moment, that this importation from private enterprises of, generically speaking, managerial culture has had, as one of its main outcomes, the adoption of an accrual based accountability, before neglected in favour of a cash based one. Let us consider, then, how this general trend has been declined in the Italian context.

## 2.2 Italian public sector modernisation: a broader picture

In Italy, business economics studies have always had a general feature focusing their attention on the broader genus-azienda than only on the species-firm. However, since the 1970s, a set of studies aiming at being downright autonomous making thus the main difference with the past tradition began to emerge thanks to the contribution of Borgonovi school of thought that showed a renewed and stronger interest for public sector entities. From then on, the deep attention for decision-making processes, planning and control systems and other issues related to the public administrations paved the way for the modernisation process that would have begun in Italy only during the last decade of the 20th century, occurring therefore with a slower pace in comparison to the forerunner countries.

Such a trend has been also encouraged by an incontrovertible point according to which the continuity and the development of any species of azienda rest on the respect of three notable principles: effectiveness, efficiency and economic performance equilibrium (from now on economy, from the Italian economicità, namely the positive balance between income and expenses). Furthermore, competitiveness, sociality and economy make up the cornerstones for evaluating the success of any entity (Coda, 1984).

In the wake of the NPM movement, in Italy better known as processo di aziendalizzazione, the national public sector witnessed profound changes that initially hit the local public administrations (as it happened, e.g., in the Federal Republic of Germany). Indeed, they gradually pioneered the shift from the traditional modus operandi to a performance-oriented management, a shift that paradoxically occurred by having solely recourse to laws (Meneguzzo, 1997; Kuhlmann, 2010).

In most of cases, the legislator in order to impinge on all those aspects considered as inherent flaws of the bureaucratic model leaned towards recommendations that aimed at making explicit how to do rather than what to do (Borgonovi, 1993). Thus, new managerial principles and tools were introduced by acting on three different types of levers:

- the re-engineering of the public sector to achieve better delivery of the basic public services through the introduction of market and/or quasi-market mechanisms into the public field (e.g. privatisation and externalisation);
- the re-definition of rules concerning the distribution of powers among the different levels of government in favour of public sector entities closer to the end users-citizens (decentralisation);

- the re-framing of performance and accountability systems by introducing new public budgeting and accounting systems (i.e., mainly, accrual accounting).

In Italy, privatisations (law no. 474/94) have been supported by the assumption that free market competition would have led to more efficient delivery of products and services. Even though privatisation appeared as a possible tool to counteract the growing public debt or, more in general, the panacea for all those problems affecting the public sector, a heated debate followed. Any choice addressed to privatise state owned entities had to be taken if and only if it could represent an opportunity to create and spread value rather than just a simple way to recover financial resources.

As regards the second point, since the mid-1990s a considerable preference for administrative federalism has emerged the all over Italian political spectrum pushing towards the decentralisation process made possible thanks to the issuing of laws such as the legislative decree no. 59/1997 and the constitutional law no. 3/2001. In a context where two antithetical forces – a centrifugal force on one side and a centripetal force on the other – were apparently in contrast with each other, the first one seemed to prevail especially when Title V of the Italian Constitution was reformed by prescribing the devolution of functions from the central to the regional and local governments. The principle of subsidiarity was definitely affirmed and the central administration would have only residual competences. Obviously, higher degrees of autonomy by local administrations imply capability to survive without recurring to systematic financial helps coming from other entities (Giannessi, 1961; Brunetti, 1994); thus, the principles of autonomy and economy are closely interlinked, feeding one another.

Lastly, the decentralisation process involves the definition of new types of accountability<sup>1</sup> (Ongaro, 2003) that, in turn, entail new forms of responsibility besides different budgeting and accounting systems. Therefore, changes in accountability codes will be accompanied by changes in the accounting tools in order to better fulfil users information needs. This would explain why Italy launched budgeting and accounting reforms addressed to the public sector to promote the shift from a cash to an accrual basis system. Among the wide range of legislative initiatives, the decree no. 77/95 is worthy of attention since it allowed relevant innovations for Italian local governments such as the introduction of an executive management plan based on objectives, programs and resources, new managerial control systems and accrual reporting (if not yet accrual accounting).

As regards the central government, the law no. 94/97 reformed the budget structure providing a different classification for revenue and expenditure accounts, the introduction of a cost centre accounting system, the zero-based budgeting approach, the basic budget unit (as voting unit) and the responsibility centres. After ten years, a new budget structure was defined by pursuing the aim of creating a direct link between the appropriated resources and the activities that have to be carried out in line with a new culture much more interested in the way public

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<sup>1</sup> Basically, it is possible to distinguish between a political accountability – that concerns the agency relationships between politicians and citizens – and a managerial accountability regarding the agency relationships between politicians and executives (Sinclair, 1995).

resources were used. However, it is worth noting how the accounting system is a component of the measurement system of an overall control system as outlined by Flamholtz (1983). Specifically, the performance management cycle (ex-art. 4 of legislative decree no. 150/2009 addressed to all public administrations) seems to show a marked analogy with such core control system presented, by the aforesaid Author, as an integrated structure consisting of four basic processes: planning, operations, measurement and evaluation-reward. Thus, the performance management cycle was part of a far-reaching reform revolving around some key-principles like transparency, integrity and meritocracy-rewards with a view to progressively improve public service quality according to the citizens perspective of their needs and both organisational and individual performance. Shortly, the reform gave more emphasis on the concept of performance (what, how and when to measure) breaking off with a former legalistic tradition focused on input control rather than on both outputs and outcomes. Moreover, a growing interest was attached to the role of the executives who saw *inter alia* their prerogatives, autonomy from the political bodies and responsibility in relation to the achieved results reinforced. Contextually, the reform envisaged the creation of a common space between politicians and administrators referred as purple zone<sup>2</sup> in Anglo-Saxon literature which sought to promote somehow an approach where the principles of separation and strategic interaction are intertwined. Traces of such cooperation can be found in articles 5 and 6 that ordain a joint work between the two actors for goal-setting and monitoring activities.

Taken as a whole, it results how over the last years the entire Italian public administration has undergone a radical overhaul affecting its traditional *modus operandi*. However, assuming that there is a linear cause and effect relationship between the reforms on one side and the changes on the other would be quite narrow. Reforms represent the first step towards a new direction but their successful implementations depend on the adoption of a strategic learning approach in place of a trivial mechanistic one as do the adoption of a holistic view rather than an atomistic one.

In order to achieve its own institutional goals, any entity has to strive in realizing a perfect harmonisation among the three distinctive fields of the business administration regarding the organisation, management and recording, respectively (Zappa, 1927). As previously announced, the Italian modernisation process started with some delay and it was somehow due to the presence of a disharmony that, in turn, has depended on the different evolution rates recorded in each of the three fields above. In particular, the next paragraph focuses on the third field with reference to a peculiar class of Sicilian subsidiary entities, whose two main qualifying characters are: to be owned by the Sicilian Region and to be public bodies.

#### 1. The case study of the Sicilian regional public bodies

Over the last decades and on the NPM-reform wave, a wide call for moving from a cash-based to an accruals-based accounting system has been recorded in a large number of public sector

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<sup>2</sup> Purple zone arises when a diagram with a circle for politics (shown as blue) intersects a circle for administrations (shown as red). The strategic conversation then takes place between the two groups giving rise to the said purple zone (Matheson, 1998).

entities across the world<sup>3</sup> as the result of several reasons (Khan and Mayes, 2009); among them one might mention the growing burden of the sovereign debt in some countries, the need to improve resource management as well as the awareness of the impossibility of getting *ad libitum* resources from the external context.

In Italy, waves of reforms addressed to introduce accounting innovations have variously involved the central, regional and local governments. In such a context, the experience of the public subsidiary entities controlled by the Sicilian Regional government represented a unique opportunity to experience new accounting systems and techniques widely discussed around the world; an experiment that has even been rounded off far in advance in comparison to what had to be launched within the Regional government itself.

In 2005, Sicily transposed the state D.P.R. no.97/2003 by the regional law no.19, hereby extending such dispositions addressed only to the state public owned bodies to all Sicilian ones. Shortly after a coordinated text followed, which had to combine the provisions of the above-mentioned decree with further modifications introduced by the decree of the President of the Sicilian government no.729/2006.

Some technical issues have been faced in 2008 when, in obedience of art.76 of the coordinated text, an *ad hoc* Committee was established to set up a chart of accounts in order to introduce an accrual basis accounting as the result of an opening towards the new without severing ties with the past tradition. The Committee was charged only for a narrow category of these public bodies: the rural Consortia for Land Reclamation. But its work represented the pilot experiment for all sort of Region owned public bodies and the main results of its work were effectively extended to other categories of Regional public bodies, with or without adaptations.

In tracing a logical path to follow, the Committee has sought to bring out changes by keeping into account, at the same time, both the regional and national context in which it was required to operate. Therefore, the Committees work programme was subdivided into some seven key points<sup>4</sup>; each of them underpinned precise fundamental choices with the ultimate end to delineate a systematic framework within which the Sicilian Regional public bodies could hopefully find a complete regulation.

First of all, the Committee interpreted its mission of drawing up the chart of accounts not in a specular way to what already performed by the central government (i.e. only flows and not also stocks and, precisely, only negative flows for the cost accounting) but in a manner that would have furthered the introduction of a complete accrual basis accounting having its own purposes. However, the introduction of such an accounting system running in parallel with the cash one has involved some problems of coordination, problems that have become much more complicated if one takes into consideration that the accounting systems to be coordinated

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<sup>3</sup> Actually, such transition has not been devoid of debates on the advantages and critical issues related to the introduction of an accrual basis accounting (Carlin, 2005; Anessi Pessina, 2007).

<sup>4</sup> These were the following: the downright chart of accounts, the surviving cash accounting system and its links with the new accrual one, the accrual accounting system, the cost centre accounting, the methods of costs allocation, the description of the items of the chart of accounts and finally some critical technical considerations (Costa, 2009).

were actually three<sup>5</sup>. Among the different methods suggested in the literature for ensuring such coordination (Tommasetti, 2008), the Committee opted for a system able to guarantee a perfect equality between the accrual and cash basis accounting while the cost accounting would have been derived from the first one being in a subordinate position. Therefore, it has been considered prudent to limit the role of the chart of accounts to the minimal goal of adding the two-accrual accounting systems without integrating them with the pre-existing cash basis accounting into a single system. Nevertheless, the Committee also contemplated the possibility to introduce more innovative and advanced methods in the future by going so far as to suppose a triple accounting system in which the cash basis accounting, the accrual financial one and the accrual cost (or management) one are tightly integrated as do the observation of both revenues and expenses within the cost (or, better, management) accounting system.

After having solved the problem of the method, the Committee had to face another important question: what kind of accounting model had to be provided for the Sicilian Regional public bodies?. Once again, it has opted for a prudent choice by keeping into account that the needs of experimentation of such entities had to be somehow subordinate to those of standardisation to avoid starting points hard to be dealt subsequently with. Thus, for each item of the chart of accounts, the Committee has advised detailed accounting and measurement principles arising from a specific accounting system the so-called *sistema del reddito e del capitale*, standing for the well-known T. DiIppolito variant (1958) of Zappas most famous accounting system<sup>6</sup>, based on flows and income as chief independent variables. Indeed, among the different variants, it seemed to be the most consistent and compatible with the international accounting standards as its logical foundations and features are closer to the *sistema del patrimonio*<sup>7</sup>, though without disregarding the advisability of introducing an accounting system more appropriate to the nature of such entities and able to provide information about their efficiency and economy. The Committee would have even raised a doubt about the real need to introduce an accrual basis accounting in line with a kind of minimalist approach. Such an approach would have been supported by the observation according to which the income in such entities could be considered a measure having a scant importance and that the net worth could be determined in a discontinuous way, too. By passing over this latter extreme hypothesis, one may believe that the Committee, although aware of such possible experimentations as, for instance, the introduction of an added value accounting system, fitter for no profit organisations, did not want

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<sup>5</sup> Indeed, the accrual accounting can be distinguished between the financial one, devoted to the general performance of the entity, and the management one, devoted to special or analytical objects. This last one, without stocks (assets and liabilities) and positive economic flows (income and revenues) reduces itself to a simple cost accounting. But this last Regional choice was not agreed by the Committee who suggested a full management accounting.

<sup>6</sup> Zappas accounting system is related to the determination of net profit (independent variable) and of capital (dependent variable). It is the Italian version, for certain aspects, of the classical American Revenues and Expenses view, stressing on flows more than on stocks. Its Italian name is *Sistema del Reddito*; from now onwards it will be briefly called the Income System.

<sup>7</sup> The alternative Italian accounting system, this time founded on stocks than on flows, roughly corresponding to the classical American Assets and Liabilities view.



to deviate too much from the most widespread practice. Thus, it limited its task to a prudent adaptation of the quoted income system within the public sector field. The accrual accounting system such as conceived by the Committee was not an end in itself but also preordained to the cost centre accounting in order to determine the cost of services provided by the Sicilian Regional public bodies and to achieve evaluation about the efficiency of the entities themselves.

As regards the cost accounting matter, the Committee was induced to get some decisions by opting for a *sistema duplice misto* the double accounting system, thought by the same DiIppolito sharing the accounting system between a financial accounting and a management linked by specific accounts, called reference accounts, that draw value from financial accounting and reclassify them for management one, in which, however, only the expenses had to be drawn from financial accounting, reclassifying them from their nature to their function<sup>8</sup>.

The coordinated law text has envisaged a subdivision of the entities in responsibility centres which, in turn, aggregated more cost centres within them; it has even been contemplated an oversimplified alternative to consider each entity as a single responsibility centre by establishing a perfect connection between the entities on the one side and the responsibility centres on the other. Moreover, entities would have a broad autonomy in identifying the cost centres but a quite limited autonomy in choosing the criteria for allocation of indirect costs in order to keep into consideration both the specificities of each entity and the real capabilities to proceed with the necessary accounting records.

After facing some technical issues, the Committee has focused its attention on the main question: the drawing up of the chart of accounts. Since its first formulation, the chart had to fulfil three unavoidable requirements:

1. it had not to be extraneous in relation to the typical administrative events of the Sicilian Regional public bodies;
2. it had not to have gaps in relation to the recurring events of an accrual basis accounting;
3. finally, it had to be prepared in order to preordain the set of information to the most relevant users (Sicilian Regional government at the top, being the major financer of such entities).

Furthermore, the chart of accounts had to be as much as possible comparable with similar classifications prevailing in the major public sector entities, above all in the Sicilian Regional government and, before that, in the central government whose classification of costs has represented a relevant reference archetype. Thus, the major sources of the chart have been represented by the State and Regional regulations along with other public experiences in which more or less analogous technical issues have been recorded.

In order to avoid a complex structure, the chart was organised on only four levels, i.e. groups, headings, ledgers and elementary accounts; the first three of these could not be modified by

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<sup>8</sup> The reclassification had to occur once a year at first, and on a quarterly basis after the first year of experimentation.

each entity while the last level could be adapted to their needs by adding other items, internal distinctions and any other change suited to the purpose.

Finally, the entities had to observe as long as compatible the national accounting principles of the Italian Standards Board (O.I.C.) and, only secondarily, the international accounting standards laid down for companies (i.e. IFRS) or those envisaged for the public sector (i.e. IPSAS).

In conclusion, the main novelty of the work carried out by the Committee has been the introduction of an accrual basis accounting system, typical of the business world, by integrating it with the traditional cash basis one because of the advantages that this latter has continued to have in terms of authorisation control of expenditure. However, the coexistence of the two accounting systems implied some inevitable technical issues and coordination problems, the resolution of which was considered necessary to guarantee a perfect operation of the new accounting system such as delineated. Thus, the Committee adopted solutions inspired by a good pragmatism ranging between two antithetical positions, namely a faithful derivation from an accounting system or from a mandatory list of rules. At the same time, it showed an aptitude to anticipate some tendencies ongoing in the national and international context rather than transposing *ad litteram* principles already widespread in the Italian public sector world and not only.

The accounting innovation that followed has not been a mechanical imitation of an accrual basis accounting system thought for the business world instead it has had its own distinct purposes that is to introduce a system able to provide measurements regarding two important indicators namely the efficiency and the economy, respectively. Thus, in relation to both the financial and cost accounting systems (the two accrual ones in three, being the third the traditional cash accounting), the Committee provided detailed accounting, measurement and allocation criteria, close to the model of the French Plan Comptable Gnral, as the result of a mingling between general principles on the one side and typical problems of such specific class of entities on the other. Although the Committees activities and the chart of accounts as outlined by itself were addressed only to the Sicilian public entities, its work represents until now a relevant opportunity for a more generalised study. Indeed, the debt towards the Civil Code intersected with the peculiarities of the public sector entities, by inducing to re-think about the nature of stocks and flows for the *azienda lato-sensu* even before for its specific classes, thus speaking of a generality rediscovered in the specificity of the theme coped by the Committee.

Finally, it is possible to draw the conclusion according to which the Sicilian Regional public bodies have embarked on a path on the wave of the then NPM movement that pointed out the need for a more or less radical change of the traditional accounting system. In such occasion, the concerned entities experienced the introduction of an accrual basis accounting (in parallel with the traditional one) by applying a chart of accounts such as the one outlined by the Committee that saw a joint collaboration between the practitioners on the one side and the academic world on the other. Although such an experience is noteworthy especially if one considers that the Sicilian Regional government has not introduced the accrual basis accounting yet, it is necessary

to regard the matter in the light of the current modified context in which the role of the public sector entities has changed over time inducing to think over about the current accountability codes but now under a critical view.

### 1. Concluding remarks

Our case study, even with interesting features, now belongs to the history of accounting. The great reformation of all public sector Italian accounting, following the Law no. 196/2009 and the derivative decrees are overwhelming, in these years, all local or regional experimentations and traditions.

A new public accounting, rooted on the so called *sistema della competenza finanziaria potenziata* (a sort of modified cash accounting system), is moving its first steps, in parallel with an accrual accounting, now generalised in its application, for the production of financial reports, which seems very similar, perhaps too similar for being really useful, to the ones thought for private businesses. This trend now concerns all Italy, and then also our little sample.

The only part of it surviving is the one concerning cost accounting, not yet involved by the national great reformation, but this surviving one, without the other two main accountings, is a non-sense waiting for a solution. But the actual situation goes beyond the scope of our work.

The relevance of this case study lies on the witness that accrual accounting for public bodies is not only easily allowable but also that its best implementation can be reached when this kind of accounting is thought originally for public and not for private entities.

The strength of this experiment is that an underlying model of stocks and flows, typical for public bodies, was thought before the introduction of it. A model where traditional revenues are systematically substituted by active transfers, the most typical positive economic flows for public bodies. Difficulties, delays and other practical issues encountered in the Sicilian history, on the contrary, concern only history and are not of scientific interest.

The case, furthermore, improves our knowledge about NPM revolution, adding a little piece in this epochal transformation. But it confirms two acquisitions, now generally agreed upon throughout the all over scientific community.

The first one is that public bodies cannot entrust all their accountability to accrual accounting. The control on economy, that is the verifying of keeping continuously an economic equilibrium between economic resources acquired and spent or consumed ones, is allowable by means of a proper accrual accounting. The control on stewardship in spending public cash, could be kept by maintaining a traditional cash accounting besides the new accrual accounting. The control on efficiency could be pursued by building upon the financial accrual accounting a fit management accrual accounting, better than only a restricted cost accounting and control. But all that will fail on effectiveness because the goal of the public body is not that of maximising the net profit, or the overall value of the entity, but to produce intangible service to the community. The production of such services could be accounted for only by means of an integrated accounting (the three bottom lines for example), in relation to which accrual accounting is only a first step, where only financial values are measured and accounted for a compulsory first step, but not sufficient for the final end of the entity.

The second one is that public bodies always have two horizons along which variables are measured: the entity itself, or the inside objective system, and the outside social system where the entity is located, or the reference system. This double perspective is not to be misunderstood with the environment for firms. For private institutions, as firms are, environment is only the scenario where they are positioned. In public institutions, the social system belongs to the function of utility in a logic of cooperation or win-win among the entity and other entities, organisations and institutions. The environment here expresses an inter-institutional horizon, opposed to the simple institutional one. In firms the inter-institutional horizon is not fully accountable (we may measure only the flows from and to environment in a logic of CSR) where we here can and must account for it in terms of stocks and flows (Bianchi, 2012). The frontier, then, of public accounting seems a full exploiting of this cash, financial, social and environmental accounting both inside the entity's boundaries and outside, in response to entity's activities (or transactions) and external events.

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# Working Papers

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## Un Modello di Massima Copertura della Domanda per l'Allocazione Ottima delle Ciclostazioni di AMAT

A Maximum Demand Coverage Model for the Optimal Location of the AMAT's Bike Sharing Stations

Andrea Consiglio · Massimo Attanasio · Stefano Fricano · Antonio Pecorella

### Riassunto

*AMAT Palermo S.p.A. è l'azienda dei trasporti pubblici del Comune di Palermo. AMAT gestisce il sistema di bikesharing e nell'ambito di un progetto di mobilità sostenibile ha coinvolto il DSEAS e quattro istituti scolastici a partecipare al progetto di ricerca "GoToSchool", un progetto volto a espandere la rete di bikesharing con l'obiettivo principale di favorire l'utilizzo della bici da parte degli studenti delle scuole medie superiori.*

*Il progetto si è sviluppato in due fasi: la prima fase è stata indirizzata alla stima della domanda del servizio di bikesharing da parte degli studenti; la seconda fase è stata dedicata allo studio di un modello di allocazione ottima delle ciclostazioni con l'obiettivo di massimizzare la domanda proveniente dagli studenti.*

*Il modello matematico di ottimizzazione permette di introdurre vincoli che tengano conto delle esigenze del committente riguardo la numerosità massima di ciclostazioni, l'inserimento in liste di inclusione o esclusione ("blacklist" o "whitelist") di un elenco di potenziali ciclostazioni per motivi legati a specifiche esigenze organizzative e progettuali, e la valutazione dell'impatto di alcuni parametri fondamentali, quali l'utilità di uno studente a recarsi a scuola utilizzando la bici, oppure, la distanza dalle varie ciclostazioni dell'indirizzo di residenza.*

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**Parole chiave** Copertura massima della domanda - Allocazione ottima delle ciclostazioni - Ottimizzazione lineare a numeri interi,

**Abstract** AMAT Palermo S.p.A. is the public transport company of the municipality of Palermo. AMAT manages the bikesharing system and within a sustainable mobility project has involved the DSEAS and four secondary schools to the research project “GoToSchool”, a project whose main aim is to foster the use of the bike by the students in getting to the school.

The project developed in two phases: the first phase was devoted to the estimate of the demand of bikesharing service from the students; the second phase was committed to the study of an optimal facility allocation problem in order to maximize the demand of bikesharing service arising from students.

The optimization model can be easily customized to account for operational requirements from AMAT, such as, the maximum number of bikesharing stations that can be installed according to the available budget, the inclusion or exclusion (“blacklist” or “whitelist”) of potential bike station places because of specific planning and organizational needs. Finally, the model provides a tool to evaluate some fundamental parameters such as, the utility to reach school by bike, or the distances between the students home address and the places of the potential bike stations.

**Keywords** Maximum demand coverage model · Optimal bikestation allocation · Linear integer optimization

## 1 Introduzione

Il progetto per lo sviluppo di un modello per l’allocazione ottima delle ciclostazioni del servizio di bikesharing di AMAT<sup>1</sup> si è articolato in due fasi. Nella prima fase, si è proceduto alla stima della domanda potenziale del servizio di bike sharing; nella seconda fase, sulla base delle richieste del committente e delle valutazioni relative al servizio in termini di costi-benefici, si è definito un modello di ottimizzazione vincolata che tenesse conto delle infrastrutture già esistenti sul territorio e dei costi sostenibili.

Il problema di allocazione ottima si configura, in letteratura, come un modello di copertura ottimale della domanda. Essi appartengono alla ampia classe di problemi matematici cosiddetti *maximal covering location problems* (si veda Murray [2016] per una rassegna aggiornata), e si basano sul concetto di allocazione di un insieme di *strutture di servizio* (facilities) con l’obiettivo di massimizzare la *copertura* di un dato servizio tramite l’allocazione di un numero fisso di strutture a disposizione. La presenza di un vincolo sulla numerosità massima delle strutture da installare è dovuto a vari fattori ed esigenze: da quelli ambientali (per esempio, ridurre

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<sup>1</sup> AMAT Palermo S.p.A. è l’azienda municipalizzata che gestisce la mobilità pubblica del Comune di Palermo. L’attività di trasporto pubblico locale si estende capillarmente per l’intero territorio cittadino, raggiungendo alcuni comuni limitrofi quali Villabate e Monreale. L’attuale rete si sviluppa per circa 330 km.

l'impatto del posizionamento di antenne di cellulari) a quelli, più frequenti, relativi al budget a disposizione degli enti erogatori del servizio.

Si osservi che nei problemi di allocazione delle risorse, e nello specifico di risorse per servizi di pubblica utilità, un fattore cruciale cui fare riferimento nel processo di costruzione del modello è porre le strutture di servizio a una ragionevole distanza dai punti di domanda: assumere ad esempio che, nella fattispecie di servizi di bike sharing, l'utente sia disposto a fare dei chilometri per raggiungere una ciclostazione porterebbe al sicuro fallimento dell'intero progetto.

Per questo motivo, una parte consistente dell'analisi è stata diretta alla stima della domanda del servizio di bikesharing da parte degli utenti (in questo caso gli studenti degli istituti scolastici che hanno partecipato alla ricerca), attingendo ai dati anagrafici in possesso delle scuole.

## 2 Stima della domanda e assunzioni di base

Gli istituti che hanno partecipato alla ricerca raccolgono un'utenza la cui provenienza abitativa è ben diversificata su tutto il territorio della città di Palermo. Il numero totale degli studenti coinvolti ammonta a 3395 unità, e sono così distribuiti:

Liceo Linguistico "Ninni Cassarà": 433 studenti.

Liceo Scientifico "A. Einstein": 790 studenti.

I.I.S.S. "Pio La Torre": 1182 studenti.

I.T.S.T. "Vittorio Emanuele III": 990 studenti.

Per ogni studente è stato possibile acquisire l'indirizzo di residenza che sarà utilizzato come fonte principale per ottenere informazioni riguardo le distanze e il tempo di percorrenza a piedi dalle potenziali ciclostazioni e da queste verso i plessi scolastici di appartenenza. A ogni indirizzo sono state associate le coordinate geografiche: longitudine e latitudine.

L'assunto principale su cui si basa la valutazione della domanda del servizio di bike sharing è la raggiungibilità a piedi da parte degli studenti delle ciclostazioni potenziali. Tale assunto non tiene conto della volontà effettiva dello studente di effettuare il tragitto casa-scuola in bicicletta. Tuttavia, si ritiene che l'ipotesi suddetta permetta una buona approssimazione della domanda effettiva in quanto (i) è legata al dato oggettivo della vicinanza alla ciclostazione, (ii) può essere facilmente ricalibrata tramite opportuni fattori correttivi e (iii), al peggio, sovrastima la domanda effettiva per tutte le potenziali ciclostazioni, annullando così l'eventuale effetto distorsivo.

Per quanto riguarda il posizionamento delle potenziali ciclostazioni, si è proceduto suddividendo l'area del Comune di Palermo oggetto dell'intervento in 84 quadrati (celle) di lato pari a 800m circa. In ogni cella si è individuato il luogo più opportuno per il posizionamento della ciclostazione, privilegiando il centroide di ogni cella. Nel caso in cui in una data cella fossero presenti altre ciclostazioni, si è proceduto indicando la ciclostazione esistente come possibile luogo

per l'installazione/ampliamento. Come per la residenza degli studenti, per ogni ciclostazione potenziale si sono registrate le coordinate geografiche.

Il fattore chiave per la stima della domanda è il tempo di percorrenza a piedi dalla residenza dello studente alle celle cui è suddivisa l'area in esame, ovvero al punto prescelto in ogni cella. Si indichi con  $\mathcal{S}_k$ ,  $k = 1, 2, 3, 4$ , l'insieme degli studenti di una data scuola e con  $S = |\bigcup_{k=1}^4 \mathcal{S}_k|$  il numero totale degli studenti coinvolti nell'analisi ( $S = 3395$ ). Si indichi, inoltre, con  $\mathcal{C}$  l'insieme delle celle in cui è stata suddivisa l'area in esame e con  $M = |\mathcal{C}|$  il numero di celle ( $M = 84$ ). Nella generica cella  $c_j \in \mathcal{C}$ ,  $j = 1, 2, \dots, M$ , potrà essere installata una ciclostazione la cui funzione è soddisfare la richiesta del servizio di bikesharing che scaturisce da  $c_j$ , oppure, della domanda che scaturisce da celle limitrofe (si veda la Sezione 3 riguardo la definizione di vicinanza fra celle). Si denoti con  $\tau_{ij}^k$  il tempo che impiega il generico studente  $s_i \in \mathcal{S}_k$  per percorrere a piedi il tragitto dalla propria residenza alla generica ciclostazione  $c_j \in \mathcal{C}$ . La domanda di servizio bikesharing per la ciclostazione  $c_j$ , proveniente dagli studenti della scuola  $\mathcal{S}_k$ , è data dal numero di studenti che possono raggiungere a piedi la cella  $c_j$  in un intervallo di tempo minore o uguale a  $\Omega$ :

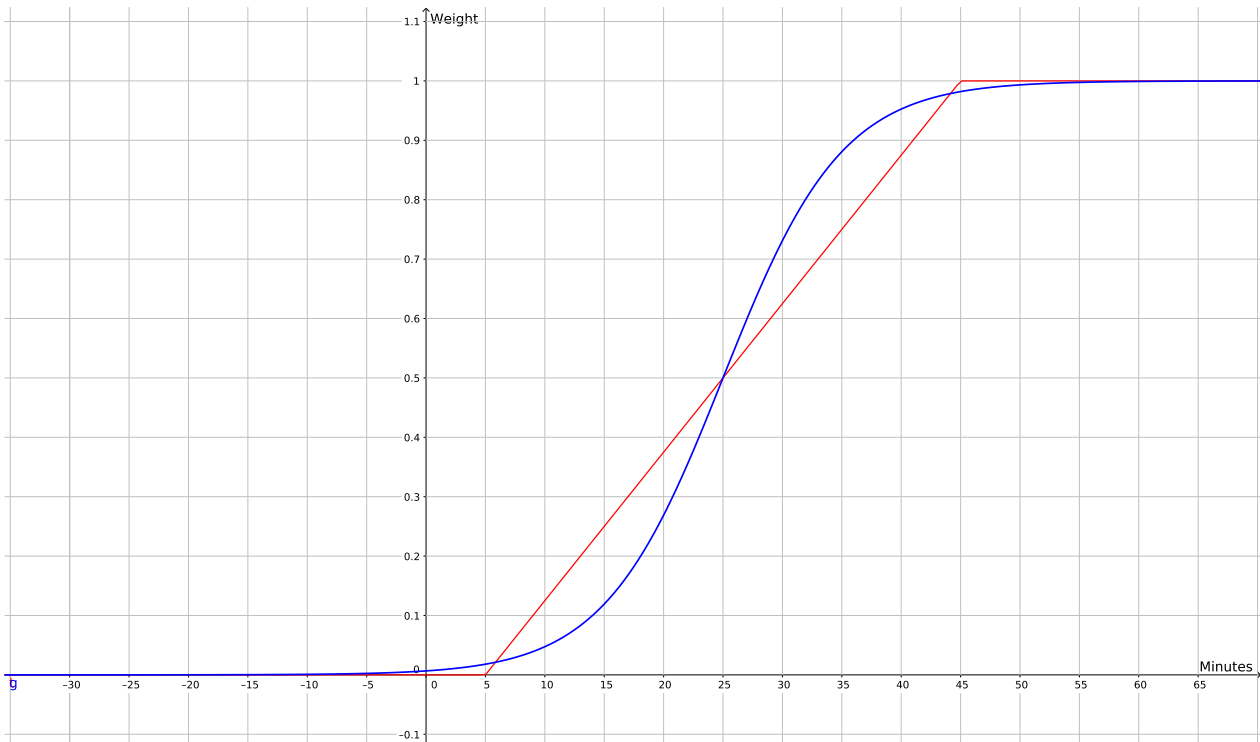
$$a_j^k = \left| \{s_i \in \mathcal{S}_k : \tau_{ij}^k \leq \Omega\} \right|. \quad (1)$$

Il livello del parametro  $\Omega$  si può ricavare da indagini sui comportamenti degli utenti di servizi similari (per esempio, car sharing), o, semplicemente, tramite un'analisi della sensibilità del sistema al variare di  $\Omega$ : valori di  $\Omega$  molto bassi implicano livelli della domanda trascurabili o nulli. Da un altro lato, valori di  $\Omega$  molto alti non sono ragionevolmente compatibili con l'erogazione del servizio in questione (un valore di  $\Omega$  relativamente alto assume la disponibilità da parte dell'utente di percorrere, a piedi, distanze maggiori).

Nella Tabella 1 sono riportati i valori di  $a_j^k$  per un sottoinsieme di celle e per  $\Omega = 12$  minuti. Nella stessa tabella è stata evidenziata la riga corrispondente alla cella n. 61, che corrisponde a una potenziale ciclostazione posizionata in prossimità dell'istituto "Einstein". Come si può notare, la domanda che scaturisce dagli studenti dell'istituto "Einstein" è molto elevata (212 studenti che frequentano l'istituto "Einstein" possono raggiungere la cella n. 61 in meno di 12 minuti), ma tale domanda è sicuramente fittizia. Infatti, gli studenti che "gravitano" attorno alla cella n. 61 vivono presumibilmente nei paraggi e non avrebbero nessuna utilità nel percorrere a piedi quella distanza per prendere una bicicletta e poi raggiungere l'istituto "Einstein".

Per ovviare a tali incongruenze, si è introdotto un correttivo dei livelli di domanda  $a_i^k$  in modo da tenere conto dell'utilità di ogni studente a raggiungere la scuola in bicicletta. Le proprietà della funzione peso sono riassunte di seguito:

1. il peso correttivo è pari a 0 se il tempo di percorrenza dalla singola cella all'istituto scolastico è trascurabile (4-5 minuti).
2. il peso correttivo è pari a 1, ovvero nessuna correzione è apportata, se il tempo di percorrenza a piedi è maggiore di 20 minuti.



**Fig. 1** La funzione sigmoide attribuisce un peso maggiore all'aumentare del tempo di percorrenza. Il peso massimo attribuibile è pari a 1.

- il peso attribuito aumenta al crescere del tempo di percorrenza. Per livelli dei tempi di percorrenza maggiori di 10 minuti, la crescita del peso avviene con incrementi decrescenti, fino alla saturazione che è pari a un peso (o utilità) pari a 1.

Si osservi che una rappresentazione più realistica della funzione di utilità dovrebbe attribuire valori decrescenti all'utilità per tempi di percorrenza maggiori di 20 minuti. In altri termini, è probabile che tempi di percorrenza a piedi molto elevati non invogliano lo studente a percorrere questa stessa distanza utilizzando la bicicletta. Come caso estremo, si considerino gli studenti che abitano nei comuni limitrofi a Palermo.

La Figura 1 mostra la funzione sigmoide che determina, in funzione del tempo di percorrenza, il peso da attribuire alla domanda ottenuta tramite l'espressione (1). Applicando il fattore correttivo alla Tabella 1, si ottiene  $\tilde{a}_j^k$ , ossia la domanda pesata per l'utilità (Tabella 2). Si osservi che la domanda imputata alla ciclostazione n. 61, relativamente all'istituto "Einstein", è adesso correttamente ridimensionata.

## 2.1 Coordinate e tempi di percorrenza

La fonte primaria di dati per la stima della domanda del servizio di bikesharing è fornita dal tempo necessario a un generico studente per raggiungere dalla propria residenza, a piedi, una potenziale ciclostazione. Come sottolineato nell'Introduzione, la prossimità di ciclostazioni nell'intorno abitativo è uno dei fattori che caratterizza la domanda del servizio di bikesharing.

I dati necessari, comunque, non sono direttamente reperibili dalle informazioni a disposizione. Nella fattispecie, i dati disponibili sono (i) gli indirizzi di residenza degli studenti e (ii) le coordinate geografiche delle potenziali ciclostazioni. Si osservi che non è possibile un'assegnazione diretta degli studenti alle diverse celle utilizzando come criterio la semplice "vicinanza geografica". Infatti, l'appartenenza di una data residenza a una cella non implica che lo studente possa raggiungere la ciclostazione a piedi in un lasso di tempo ragionevole. Inoltre, assegnare uno studente a una singola cella è un'operazione del tutto arbitraria, in quanto escluderebbe la possibilità che lo stesso studente utilizzi altre ciclostazioni che si trovano nei paraggi e raggiungibili entro l'intervallo di tempo fissato. Infine, allocare "manualmente" un numero così elevato di studenti nelle varie celle è un'operazione particolarmente lunga, complessa e suscettibile di errori materiali.

Un'alternativa praticabile consiste nell'utilizzo di metodi numerici che stabiliscono i tempi di percorrenza in funzione della distanza fra le coordinate geografiche di due punti. Si osservi, però, che la distanza spaziale non permette di ottenere la corretta stima del tempo di percorrenza in quanto, come è ovvio, la distanza "in linea d'aria" può essere molto diversa dai percorsi che effettivamente uniscono due luoghi di una città (alla base dei modelli che trasformano le coordinate geografiche in tempi di percorrenza vi sono ipotesi che sono legate a tessuti urbani con sistemi viari molto regolari).

Per questi motivi si è preferito fare ricorso ai servizi offerti dal motore di ricerca di Google Map, in grado di elaborare il tempo di percorrenza a piedi e la distanza in chilometri tra punti di cui sono note le coordinate geografiche. Purtroppo, la dimensionalità del problema non permette di effettuare la ricerca accedendo al noto servizio disponibile sul web tramite appositi programmi software per il *web scraping*<sup>2</sup>. Si tratta, infatti, di acquisire (e salvare in un file) le coordinate geografiche dei domicili di tutti gli studenti, e, successivamente, di ottenere circa 300.000 tempi di percorrenza (esattamente,  $S \times M = 285.180$ ), con tempi di calcolo proibitivi (fino a 24 ore per il solo istituto "Einstein").

Per ovviare a questi tempi non accettabili, si è preferito accedere direttamente ai motori di Google Map tramite delle API (Application Programming Interface), ossia delle librerie software dedicate a eseguire un compito preciso. Nello specifico, si è utilizzato uno script in Python e le API collegate al servizio `Google Direction` per ottenere le coordinate geografiche degli indirizzi degli studenti e la matrice dei tempi di percorrenza residenza-ciclostazione. Il

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<sup>2</sup> Il *web scraping* o *web harvesting* è una tecnica informatica di estrazione di dati da un sito web per mezzo di programmi software come, per esempio, `IMacros`, o strumenti di Python (`Scrapy`).

tempo necessario per completare la matrice dei tempi di percorrenza, per tutte le scuole, è stato così inferiore alle 3 ore.

Nella Figura 2 sono riportate con un box plot le distribuzioni dei tempi per effettuare a piedi il percorso dalla residenza di ogni studente alle celle contenenti le potenziali ciclostazioni, rispettivamente, per l'istituto Vittorio Emanuele III (sopra) e per l'istituto Cassarà (sotto). Più significativi sono i grafici descritti in Figura 3. Essi, infatti, riportano il numero di studenti che hanno come prima scelta, in termini di vicinanza, una delle possibili ciclostazioni. Il grafico relativo all'Istituto "Einstein" (sopra) rivela che la cella n. 61 ha un numero consistente di studenti che gravitano intorno ad essa. Tuttavia, questo numero non rappresenta la domanda effettiva, in quanto inficiato dalla loro prossimità abitativa all'istituto "Einstein".

### 3 Il modello di massima copertura della domanda

In ogni cella la domanda del servizio di bikesharing è data dalla somma delle domande degli studenti delle quattro scuole coinvolte nello studio. Si indichi con  $\tilde{a}_j$  la domanda pesata che è attribuita alla  $j$ -esima cella, dove,

$$\tilde{a}_j = \sum_{k=1}^4 \tilde{a}_j^k, \quad (2)$$

e,  $j = 1, 2, \dots, M$ .

Si osservi che nella stima di  $\tilde{a}_j$  si è anche ipotizzato che lo studente che afferisce alla  $j$ -esima cella possa utilizzare ciclostazioni limitrofe. In altri termini, la domanda associata alla cella  $c_j$  potrebbe essere soddisfatta da ciclostazioni presenti nell'intorno di  $c_j$ .

A tal scopo, per ogni  $c_j \in \mathcal{C}$ , si è individuato l'insieme delle ciclostazioni che possono essere raggiunte a piedi in meno di  $\xi$  minuti:

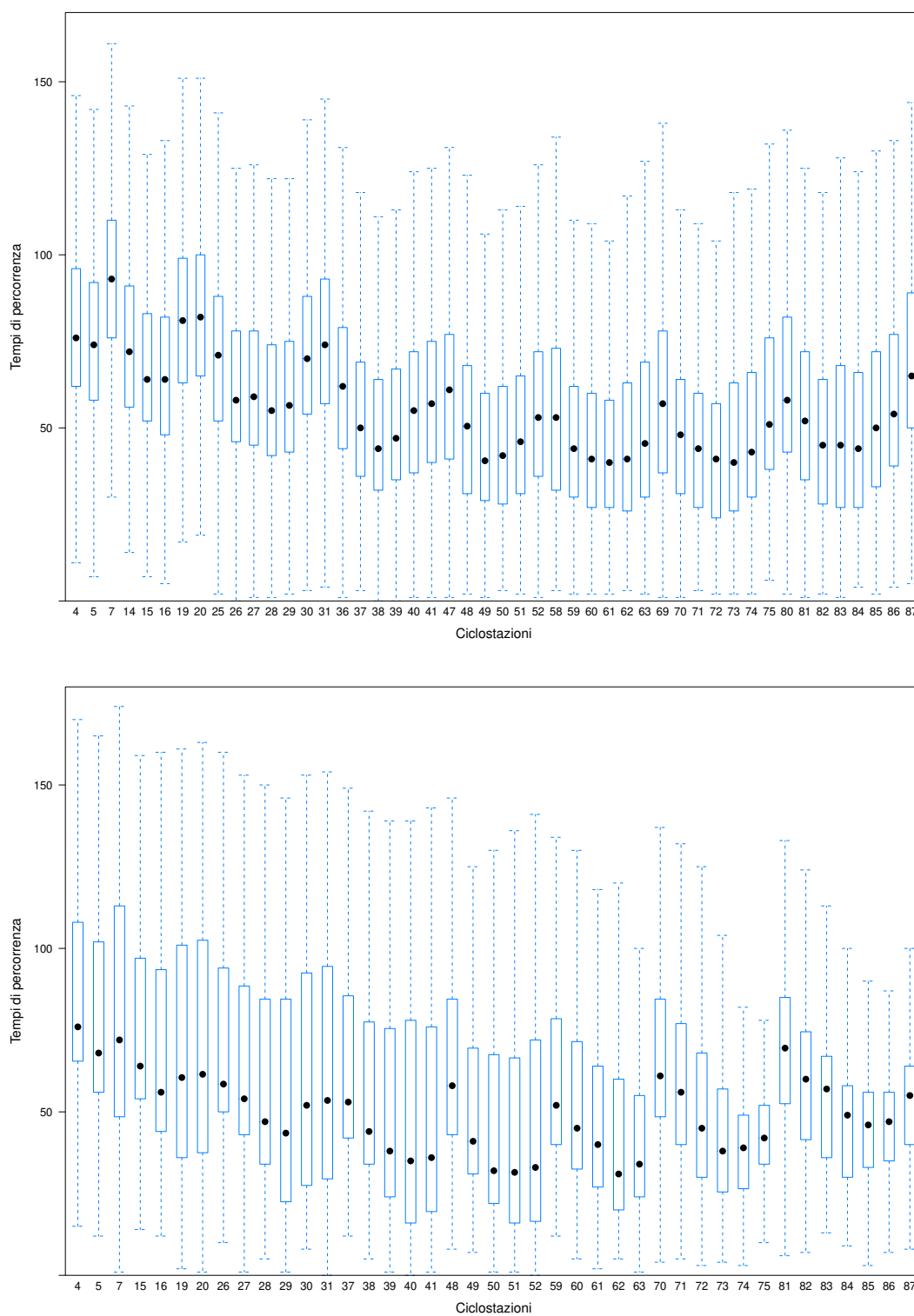
$$\mathcal{N}_j = \{c_i \in \mathcal{C} : \tau_{ij} \leq \Omega\}, \quad (3)$$

dove  $\Omega$  è stato posto a 15 minuti e  $\tau_{ij}$  misura il tempo di percorrenza, a piedi, per raggiungere la ciclostazione posta nella cella  $c_j$  dalla cella  $c_i$ . Si noti che le ciclostazioni dell'insieme  $\mathcal{N}_j$  non sono sempre quelle spazialmente adiacenti alla ciclostazione  $c_j$ , in quanto potrebbe non essere sufficiente raggiungere la ciclostazione  $c_j$ , a piedi, nell'intervallo di tempo previsto  $\xi$  (si veda la sezione 2.1).

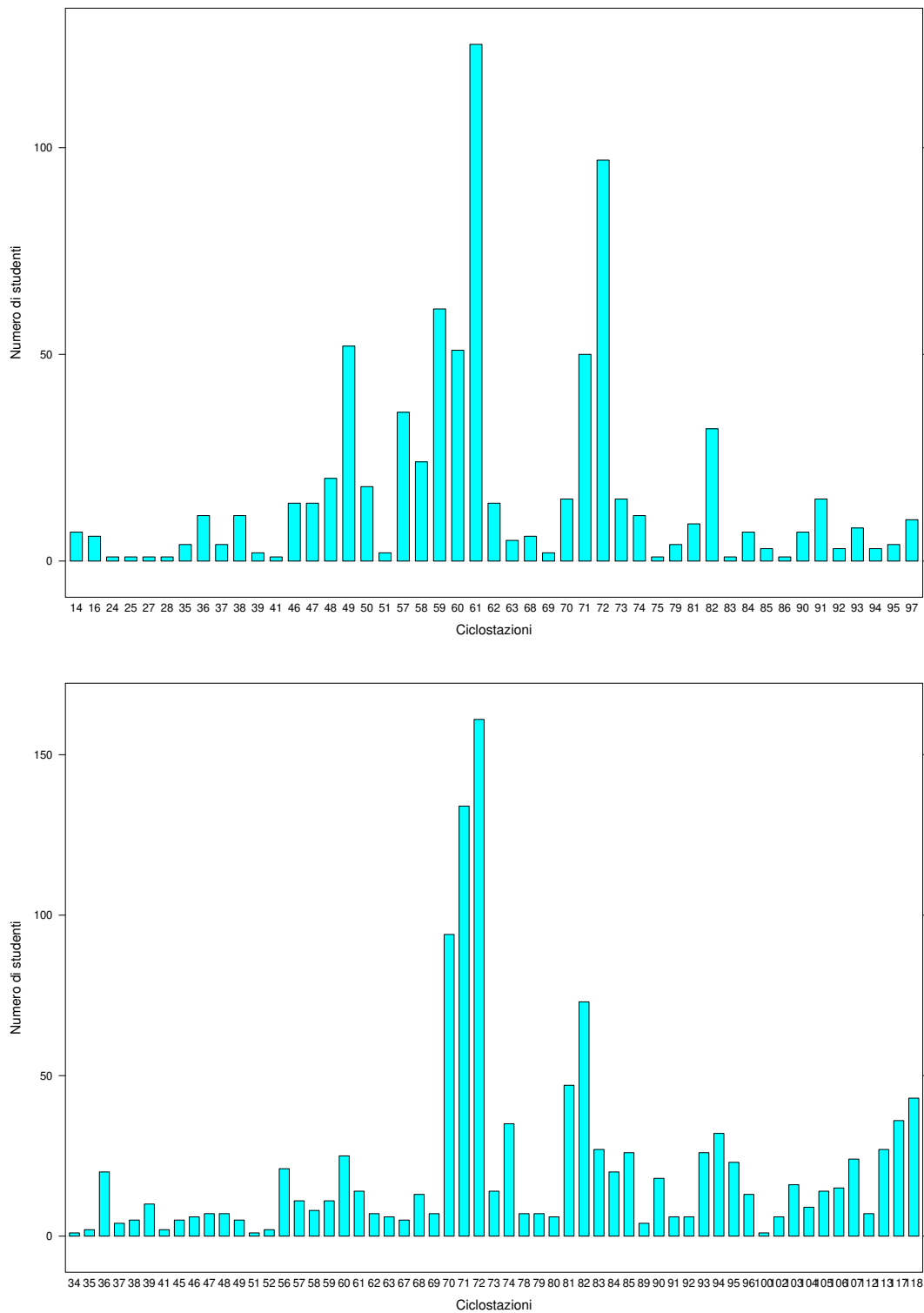
Si definisca con  $Y_j$  una variabile che può assumere soltanto i valori 0 e 1, per ogni  $j = 1, 2, \dots, M$ . Se  $Y_j = 1$ , allora la domanda proveniente dalla cella  $c_j$  è soddisfatta. Si osservi che tale domanda può essere esaudita o dall'allocazione di una ciclostazione nella cella  $c_j$ , oppure da ciclostazioni allocate nelle celle limitrofe a  $c_j$ .

L'ammontare di domanda soddisfatta dalla ciclostazione  $c_j$  è semplicemente dato da  $\tilde{a}_j Y_j$ . La funzione che definisce la domanda totale proveniente dal sistema è data da:

$$D = \sum_{j=1}^M \tilde{a}_j Y_j. \quad (4)$$



**Fig. 2** Box plot delle distribuzioni dei tempi di percorrenza residenza-ciclostazione per gli studenti dell'istituto "Vittorio Emanuele III" (sopra) e per l'istituto "Cassarà" (sotto).



**Fig. 3** Numero di studenti dell’istituto “Einstein” (sopra) e dell’istituto “Pio La Torre” (sotto) che hanno come prima scelta, in termini di vicinanza, una delle potenziali ciclostazioni. Si osservi che le ciclostazioni n. 61 e n. 71, che registrano il maggior numero di studenti, sono posizionate, rispettivamente, in prossimità dell’istituto “Einstein” e dell’istituto “Pio La Torre”.



Se tutte le variabili  $Y_j$  fossero pari ad 1, allora la domanda sarebbe interamente soddisfatta. Chiaramente, nel caso di risorse illimitate, la domanda può essere interamente soddisfatta allocando una ciclostazione in ogni cella (in realtà, non è necessario allocare una ciclostazione in ogni cella, per l'ipotesi che la domanda può anche essere soddisfatta da ciclostazioni limitrofe).

Si indichi con  $X_i$  una variabile decisionale binaria che assume valore 1 se la ciclostazione è allocata nella cella  $c_i$ , 0 altrimenti, con  $i = 1, 2, \dots, M$ . Sia, inoltre,  $N$  il numero massimo di ciclostazioni che è possibile realizzare. La soluzione ottima che massimizza la domanda totale  $D$  deve essere vincolata in modo che la somma delle variabili  $X_i$  non sia maggiore di  $N$ , in simboli,

$$\sum_{i=1}^M X_i \leq N. \quad (5)$$

Come descritto sopra, la domanda di una cella può essere servita da installazioni nelle celle limitrofe. Se  $Y_j = 0$ , allora nelle celle dell'intorno di  $c_j$  non sono state allocate ciclostazioni e, quindi, la somma delle variabili binarie  $X_i$  nell'intorno di  $\mathcal{N}_j$  sarà pari a zero. Se in almeno una cella  $c_i \in \mathcal{N}_j$  è stata allocata una ciclostazione ( $X_i = 1$ ), allora sarà  $Y_j = 1$ . Da un punto di vista matematico, ciò è equivalente a imporre i seguenti vincoli:

$$Y_j \leq \sum_{i=1}^{|\mathcal{N}_j|} X_i, \quad (6)$$

per ogni  $j = 1, 2, \dots, M$ .

Il modello di ottimizzazione è descritto dalle seguenti equazioni:

$$\text{Massimizza}_{\substack{X_i \\ i=1,2,\dots,M}} D = \sum_{j=1}^M \tilde{a}_j Y_j \quad (7)$$

soggetto a

$$\sum_{i=1}^M X_i \leq N \quad (8)$$

$$\sum_{i=1}^{|\mathcal{N}_j|} X_i \geq Y_j, \quad \text{per ogni } j = 1, 2, \dots, M, \quad (9)$$

$$X_i = \{0, 1\} \quad \text{per ogni } i = 1, 2, \dots, M, \quad (10)$$

$$Y_j = \{0, 1\} \quad \text{per ogni } j = 1, 2, \dots, M. \quad (11)$$

Il modello (7)–(11) si configura come un problema di programmazione matematica lineare a variabili intere con  $M + 1$  vincoli e  $2M$  variabili. Il modello è stato implementato in GAMS [Brooke et al., 1992, Consiglio et al., 2012], un meta-linguaggio specifico per problemi di ottimizzazione, utilizzando CPLEX [IBM, 2018], un algoritmo per la soluzione di problemi di ottimizzazione lineare a variabili intere.

Il modello è abbastanza flessibile e offre la possibilità di introdurre vincoli che limitano o favoriscono l'installazione di ciclostazioni in specifiche celle. Per esempio, nella fase esecutiva, il committente ha ritenuto non fattibile installare delle ciclostazioni in zone non ancora servite da piste ciclabili, oppure in celle che fossero già servite da una o più ciclostazioni. Queste ulteriori informazioni sono state inserite nei vincoli del modello in modo che la scelta ottimale tenesse conto di queste nuove istanze. In maniera analoga, ma con un intervento di segno opposto, si è chiesto al modello di includere nella soluzione ottima ciclostazioni in prossimità delle Stazioni Centrale e Notarbartolo, al fine di erogare un servizio per i pendolari e per quegli studenti che vivono nelle zone periferiche servite dal tram (Brancaccio e Borgo Nuovo), ma che non hanno piste ciclabili nel loro territorio.

Da un punto di vista matematico, i vincoli di "esclusione" e "inclusione" si possono rappresentare tramite delle equazioni in cui le variabili  $X$  sono definite su specifici insiemi e opportunamente vincolate. Gli insiemi prendono il nome di "blacklist" (e si indica con  $\mathcal{B}_{\mathcal{L}}$ ) e "whitelist" (e si indica con  $\mathcal{W}_{\mathcal{L}}$ ): il primo contiene l'insieme delle celle che si vogliono escludere, mentre, il secondo definisce l'insieme delle celle da includere. Le equazioni dei vincoli sono date da,

$$\sum_{i=1}^{|\mathcal{B}_{\mathcal{L}}|} X_i = N_B \quad (12)$$

$$\sum_{i=1}^{|\mathcal{W}_{\mathcal{L}}|} X_i = N_W, \quad (13)$$

dove  $N_B$  e  $N_W$  indicano, rispettivamente, il numero di celle che si vuole escludere e quelle che si vuole includere. Per esempio, se  $N_B = 0$  tutte le celle  $c_i \in \mathcal{B}_{\mathcal{L}}$  saranno escluse dalla soluzione ottima. Se, invece,  $N_B > 0$ , allora soltanto  $N_B$  celle saranno escluse e sarà l'algoritmo che sceglierà quali celle dell'insieme  $\mathcal{B}_{\mathcal{L}}$  escludere, dati i vincoli e l'obiettivo di massimizzazione della domanda.

Per quanto riguarda il vincolo di inclusione, di solito,  $N_W > 0$ , inoltre, se  $N_W$  è uguale al numero di celle dell'insieme  $\mathcal{W}_{\mathcal{L}}$  ( $N_W = |\mathcal{W}_{\mathcal{L}}|$ ), allora tutte le celle in whitelist saranno incluse nella soluzione ottima. Nel caso in cui  $0 < N_W < |\mathcal{W}_{\mathcal{L}}|$ , allora sarà il modello a scegliere in maniera ottimale quali celle includere nella soluzione ottima.

Nella Figura 4 è raffigurata la soluzione ottima per  $N = 10$ . Le celle di colore grigio chiaro sono state selezionate dal modello di ottimizzazione e rappresentano le variabili  $X$ ; le celle in giallo, che rappresentano le variabili  $Y$ , sono quelle la cui domanda è soddisfatta in quanto limitrofe alle celle ottime. Le celle in grigio scuro fanno parte della black list, mentre quelle in chiaro non sono soddisfatte dalla soluzione corrente. La domanda totale che è soddisfatta dalla soluzione ottima è  $D = 2346$  unità.

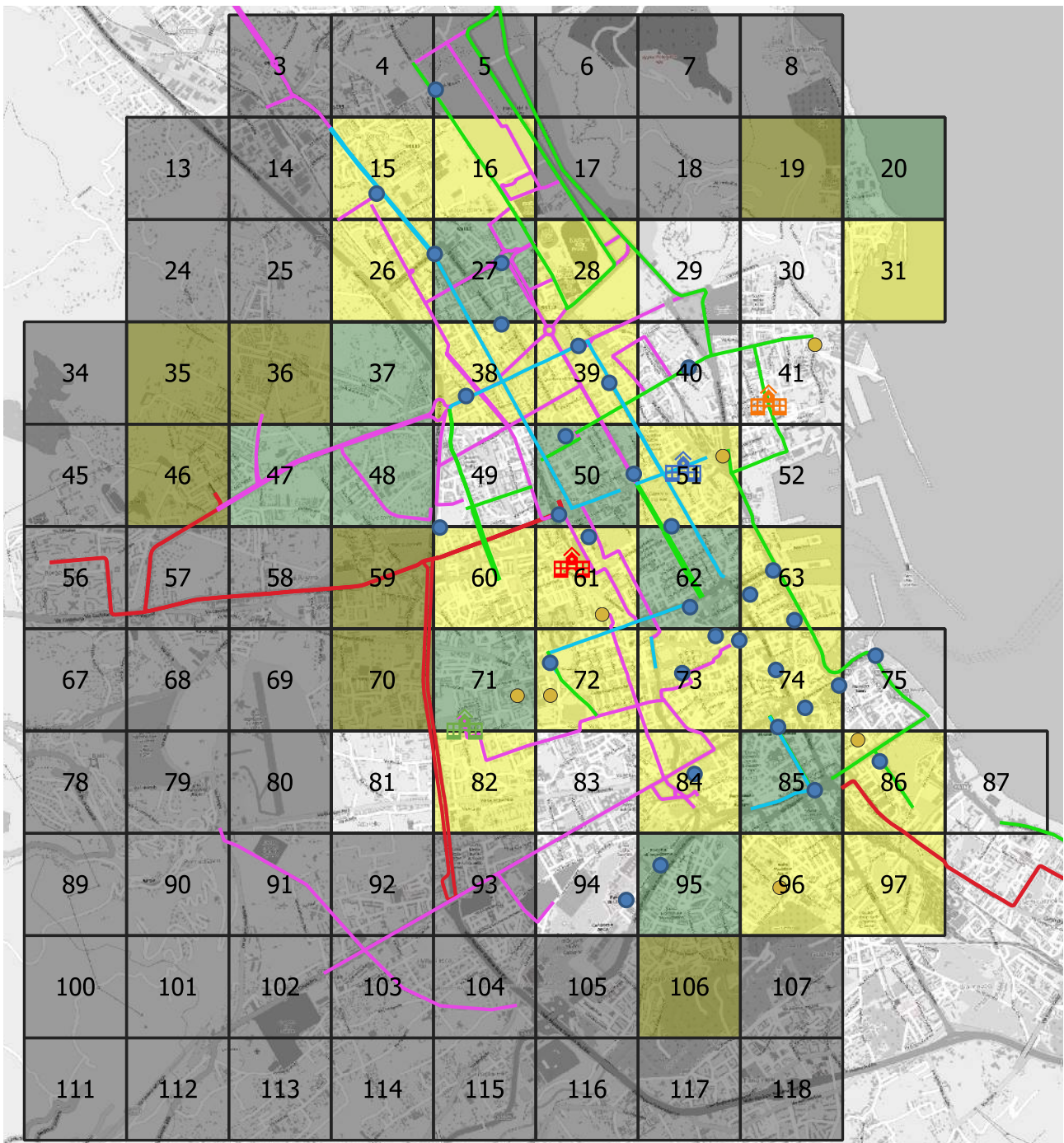
La Figura 5 (sopra) mostra la soluzione ottima con  $N = 15$ . Si osservi che la sola cella in bianco è la n. 30 e, di conseguenza, il livello ottimo della domanda soddisfatta  $D$ , pari a 2559 unità, è maggiore rispetto al caso con  $N = 10$ .

Infine, nella Figura 5 (sotto) si riporta la soluzione ottima per  $N = 20$ . In questo esempio, il numero delle celle ottime è pari a 17 ed è inferiore al numero massimo ammesso. Il modello è, quindi, conservativo rispetto al numero di celle da allocare. In altri termini, il modello privilegia soluzioni che massimizzano la domanda e che, a parità di risultato, dispongano di un numero minore di celle allocate. Questo risultato è possibile in quanto, come già più volte sottolineato, la domanda del servizio può essere soddisfatta tramite le celle che insistono nell'intorno delle celle ottimali. Per questa configurazione ottima, il livello della domanda soddisfatta è pari a  $D = 2570$  unità.

L'esercizio appena descritto permette di ottenere informazioni anche sul numero ottimale di  $N$  tramite un'analisi del guadagno marginale che si otterrebbe aggiungendo ulteriori ciclostazioni. In particolare, si osservi che il passaggio da  $N = 15$  a  $N = 20$  permette un guadagno marginale trascurabile in termini di domanda soddisfatta. Infatti, per  $N = 15$  la domanda ottimale è pari a  $D = 2559$ , mentre per  $N = 20$  si ha che  $D = 2570$ , con un guadagno di appena 11 unità, ovvero di 0.4% della domanda rispetto a  $N = 15$ . Più consistente è il guadagno marginale nel passaggio da  $N = 10$  a  $N = 15$ . In questo caso la domanda marginale soddisfatta dall'aggiunta di 5 ciclostazioni è di circa il 9%.

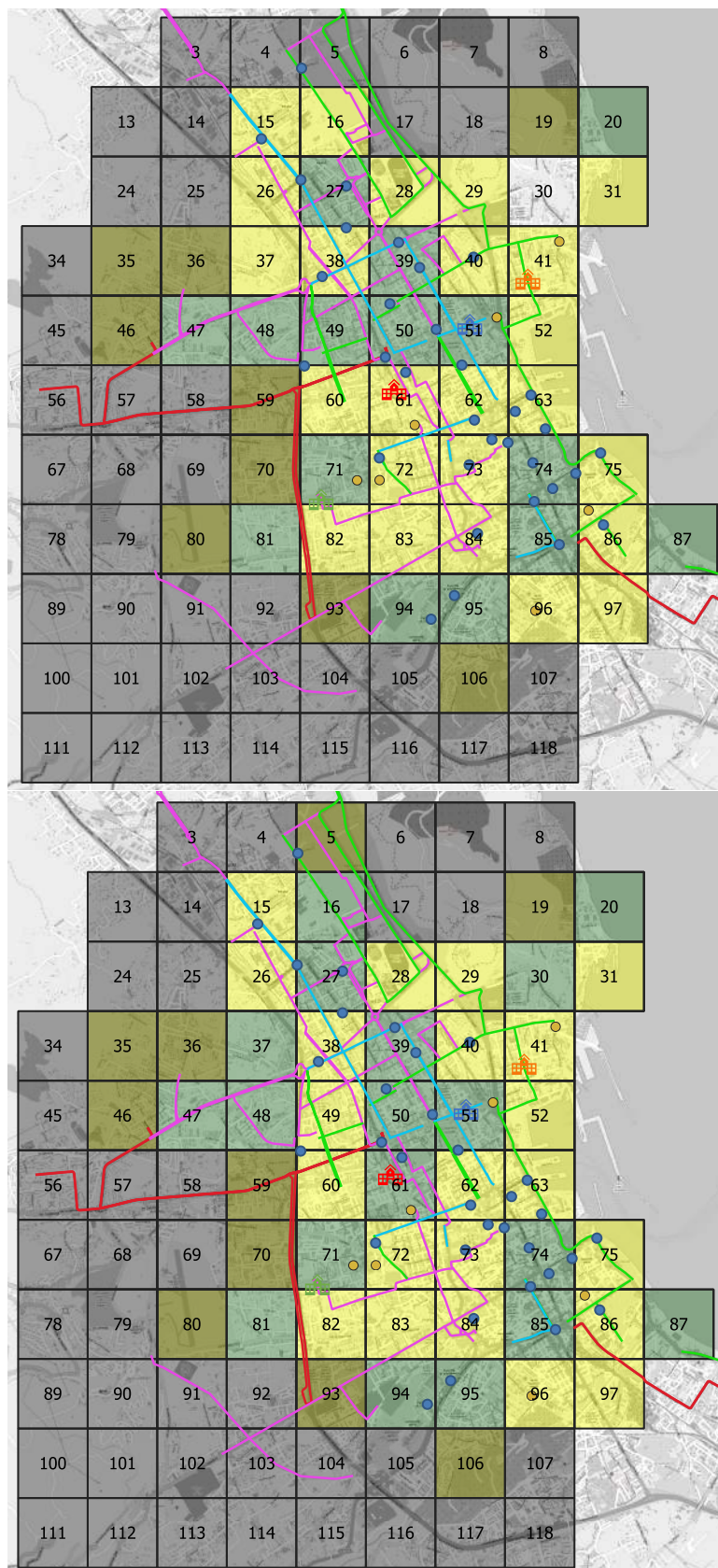
## 4 Conclusioni

Il modello di allocazione ottima delle ciclostazioni per il servizio di bikesharing di AMAT si articola in due fasi: la prima fase è dedicata alla stima della domanda che scaturisce da ogni cella in cui è stato suddiviso il territorio della città di Palermo oggetto dell'intervento. Nella seconda fase, si è messo a punto un modello di ottimizzazione con l'obiettivo di massimizzare la domanda totale, dati i vincoli di numerosità massima delle ciclostazioni da installare, e alcuni vincoli relativi alla specifiche richieste del committente. Un elemento che risulta essere di particolare importanza nella fase di progettazione è la possibilità di valutare il guadagno marginale in termini di domanda soddisfatta derivante dall'incremento di un'unità di ciclostazione. Dalla descrizione dei vari passaggi, si evince che la tecnologia e le metodologie analizzate sono disponibili in termini operativi a qualsiasi utilizzatore, sia per quanto riguarda l'accesso alle informazioni sui tempi di percorrenza (i database di Google) sia per quanto riguarda i tempi computazionali.



**Fig. 4** Soluzione ottima con  $N = 10$  ciclostazioni. Le celle in grigio chiaro rappresentano le variabili  $X$  e sono state scelte per l'installazione di una ciclostazione. Le celle in giallo rappresentano le  $Y$  e sono quelle la cui domanda è soddisfatta in quanto limitrofe alle celle ottime. Infine, le celle in grigio scure fanno parte dell'insieme delle celle in blacklist.





**Fig. 5** Soluzione ottima con  $N = 15$  (sopra) e  $N = 20$  ciclostazioni (sotto).

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Identificativo Cella	Cassarà	Einstein	Pio La Torre	Vittorio Emanuele III	Domanda Totale Pesata
37	1	8	3	18	30
38	6	42	7	21	76
39	38	11	2	31	82
40	72	2	1	61	136
41	81	2	3	65	151
45	0	0	12	0	12
46	0	27	13	0	40
47	0	36	18	40	94
48	2	38	10	24	74
49	7	120	7	33	167
50	37	44	2	34	117
51	62	13	4	47	126
52	77	2	3	60	142
56	0	0	19	0	19
57	0	27	32	0	59
58	0	55	31	32	118
59	1	91	23	26	141
60	5	171	55	45	276
61	32	212	70	60	374
62	47	53	19	38	157
63	28	13	16	33	90
67	0	0	5	0	5
68	0	21	24	0	45
69	0	27	27	18	72
70	3	36	154	46	239
71	14	99	273	61	447
72	21	213	295	103	632
73	39	58	68	90	255
74	29	20	42	73	164
75	1	0	0	8	9
78	0	0	8	0	8
79	0	2	18	0	20
80	0	2	29	13	44

**Table 1** Numero di studenti, per scuola di appartenenza, che possono raggiungere a piedi le diverse celle in un lasso di tempo inferiore a  $\Omega = 12$  minuti. La numerosità definisce la domanda del servizio di bikesharing.

Identificativo Cella	Cassarà	Einstein	Pio La Torre	Vittorio Emanuele III	Domanda Totale Pesata
37	1.00	6.15	2.90	17.42	27.47
38	5.84	18.91	6.67	17.47	48.89
39	20.89	8.82	1.99	4.40	36.10
40	7.18	1.72	1.00	8.65	18.55
41	0.54	1.76	2.99	6.48	11.78
45	0.00	0.00	11.99	0.00	11.99
46	0.00	26.90	12.93	0.00	39.83
47	0.00	35.56	17.73	39.96	93.25
48	2.00	27.78	8.32	23.22	61.32
49	6.73	11.97	5.38	18.14	42.22
50	22.15	6.24	1.80	2.35	32.54
51	6.18	4.61	3.89	0.31	15.00
52	1.14	1.54	2.99	2.85	8.51
56	0.00	0.00	18.96	0.00	18.96
57	0.00	26.60	30.97	0.00	57.57
58	0.00	47.20	23.82	31.68	102.70
59	1.00	40.97	9.23	23.84	75.03
60	4.87	24.26	24.76	29.05	82.94
<b>61</b>	<b>29.79</b>	<b>1.42</b>	<b>35.00</b>	<b>27.01</b>	<b>93.22</b>
62	32.43	6.32	14.60	5.39	58.74
63	19.32	6.50	14.89	8.88	49.59
67	0.00	0.00	4.99	0.00	4.99
68	0.00	20.75	22.86	0.00	43.61
69	0.00	26.13	23.78	17.96	67.87
70	3.00	28.88	18.36	45.69	95.93
71	13.99	59.27	2.23	60.26	135.75
72	20.75	25.39	20.40	90.72	157.25
73	35.11	15.60	46.92	53.88	151.51
74	26.99	13.80	37.81	47.13	125.74
75	0.95	0.00	0.00	6.87	7.82
78	0.00	0.00	7.99	0.00	7.99
79	0.00	2.00	17.68	0.00	19.68
80	0.00	2.00	21.20	13.00	36.20

**Table 2** Domanda pesata con l'utilità di raggiungere la scuola in bici. La domanda imputata alla cella n. 61, relativamente agli studenti dell'istituto "Einstein", è notevolmente ridotta a causa del livello di utilità quasi pari a zero.







## A Note on Economic Impact of EFF on Sicilian Firms Performance

Fazio Gioacchino · Fricano Stefano

**Abstract** The measure 2.3 of the European Fisheries Fund, in Sicily, claimed investments of fish firms in production capacity expansion and modernization of fish processing.

Have these investments been effective in supporting the competitiveness of these firms and have they influenced the economic sustainability of the regional seafood chain?

Proposed counterfactual analysis contributes to this assessment through comparison of business performance of funded and non-funded firms.

**Keywords** Counterfactual analysis · Data Envelopment Analysis · Business Performance · Fishery sector

### Riassunto

*All'interno del programma operativo Fondo Europeo per la Pesca (FEP 2007-2013), in Sicilia, l'UE ha sostenuto finanziariamente, con la misura 2.3 (Investimenti nei settori della trasformazione e commercializzazione), le imprese del settore della trasformazione dei prodotti ittici negli investimenti mirati ad ampliare la propria capacità produttiva ed ammodernare i propri impianti.*

*In che misura tali interventi sono stati efficaci nel sostenere la competitività del settore della trasformazione dei prodotti ittici e in che modo hanno inciso sulla sostenibilità economica della filiera ittica regionale?*

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*Lo studio proposto contribuisce a tale valutazione attraverso un'indagine esplorativa presso le imprese beneficiarie dei contributi pubblici e un'analisi della variazione delle loro performance aziendali.*

**Parole chiave** *Analisi Controfattuale, DEA, Business Performance, Settore Ittico*

## 1 Introduction

The EU Structural Funds are the most important source of funding for business support mechanisms in many European regions. The need for an evaluation of these mechanisms is widely recognized. Recently, the European Commission has asked for a more rigorous and in-depth analysis of the impact of these policies and it was urged the member countries to take a quantitative approach to its assessment (EC (2015)).

Several studies have been conducted on specific countries, regions or specific areas, for examples: Lima and Cardenete observe a positive relation between Structural Funds and their impact on economic growth of South of Spain Lima and Cardenete (2008) and Percoco analysed the impact of European funds in the area of the Italian Mezzogiorno Percoco (2005).

It's interesting to underline the recent approach of Dvouletý and Blažková (Dvoulet and Blakov (2018)) who applied counterfactual impact analysis based on firm-level data with the aim of investigating the effects of this support on the financial performance of the supported firms two years after the end of intervention. Results show a positive effect on the performance of supported firms measured by price-cost margin, value added per labour cost, growth of sales and growth of tangible assets. The use of counterfactual method for impact analysis has already been used for a long time and is considered among the most reliable (Martini (2009)).

This note aims to offer an empirical contribution to evaluate the impact of European structural funds on the Sicilian fish processing firms performance. The proposed impact evaluation is based on the method of counterfactual analysis in which the performances of the firms funded are compared to those not funded. The performances are measured with a composite indicator, named *Business Performance* (BP), obtained by applying a *Data Envelopment Analysis* linear programming model in a BOD framework.

## 2 Fish processing sector

The results of the 2017 EU fish processing sector analysis made by STECF (STECF (2017)) show that in 2015 the sector consisted of around 3,600 firms (fish processing as main activity), of which 57% were microfirms with less than 10 employees.

In general, 2015 data show a deterioration of the economic performance if compared to 2014 (e.g. GVA and net profit were respectively 14% and 21% lower than in 2014) even if the sector still remain profitable.

The Italian fish processing industry has been characterized, in 2015, by a total number of firms equal to 785 units, producing a turnover of about 2.8 billion €.

The Italian fish processing industry is characterized by two different typology of organization on the market: on one hand, there is a modern sector, made up of few large industrial firms, and, on the other hand, there is the traditional sector, highly atomized and formed mainly by micro, small and medium-sized firms, many of which are organized on a family basis. The 77% of firms is represented by microfirms, with less than 10 employees. In general, looking at the other dimensional classes, it can be strongly asserted that the Italian fish processing industry is dominated by small firms, as 97% of firms are represented by firms with less than 50 employees. As far as the geographical localisation, the large part of firms is located in the Southern Italy and in the islands (Sicily and Sardinia). Indeed, over 50% of firms are concentrated in four regions, such as: Sicily (23%), Calabria (11%), Campania and Veneto (9% each). Sicily is, by far, also the region with highest number of employees (20% of the national total).

### 3 Methodology and model: a firm performance index

For our goals we propose a composite indicator to synthesize the performance of firms using four indicators of performances, for each year in the time span 2006-2015, that is:

- ROA: return on assets, which measures the profitability on the invested capital, it measures the net income produced by total assets during a period by comparing net income to the average total assets;
- ROE: return on equity, which measures the return on equity;
- ROI: return on investment, which indicates the profitability and economic efficiency regardless the resources used, it expresses what makes the capital invested in that firms
- ROS: return on sales, it represents the profitability of sales index measured by the ratio between the operating result and net revenues on sales.

Data availability allow to calculate the composite indicator for the time span 2006-2015.

The use of four different indicators (ROA, ROE, ROI and ROS) requires an adequate representation of the position of each firm for the period of interest. So, the Performance Index (PI) is obtained by applying a Data Envelopment Analysis method with proportion restrictions on weights calculated in a Benefit-of-Doubt approach. In this way, we avoid subjective opinions by experts and we avoid the use of identical weights (as in the case of a simple arithmetic mean); on the contrary, weights are determined endogenously by optimizing the position of every firm on each of the four basic indicators. In particular, to exclude the possibility of zero values that eliminate the contribution of some dimensions, we add restrictions on the minimum weights.

In this way, the composite indicator for firm is compared with the benchmark composite indicator:

$$BP_{c,score} = \frac{\sum_{i=1}^m w_{i,c} y_{i,c}}{\sum_{i=1}^m w_{i,c} y_{i,best}} \quad (1)$$

where

$y_{i,best} \equiv$  *endogenous benchmark*

$BP_{c,score}$  is clearly between 0 (the worst performance among the firms under investigation) and 1 (the best performance).

The weighting problem can be handled for each firm separately with weights endogenously computed that, thus, can vary among firms and indicators. These weights may be chosen optimally, for example by ensuring the best combination of the four basic indicators to get a  $BP_j$  as high as possible with the benefit-of-the-doubt, that is

$$BP_{c,score}^* = \max \left( \frac{\sum_{i=1}^m w_{i,c} y_{i,c}}{\max_{y_{i,j}} \sum_{i=1}^m w_{i,c} y_{i,j}} \right) \quad (2)$$

In this way, firm  $c$  has always the highest possible score in relation to other firms under investigation. To avoid zero weights, we also add restrictions in terms of proportional share

$$inf_{i,j} \leq \left( w_{i,j} y_{i,j} / \sum_{i=1}^m w_{i,j} y_{i,j} \right) \leq sup_{i,j} \quad i = 1, \dots, m \quad j = 1, \dots, n \quad (3)$$

In our case, we assume a lower bound equal to 20% with an upper limit determined accordingly to 1.

## 4 Data

The data used in this analysis were obtained by crossing two different databases as show in Fig.1. On the one hand we used the data made available by the Department of Mediterranean Fisheries of the Sicilian region; in particular, we used data relating to three different calls issued by the Department about investments in processing and marketing (measure 2,3 of EFF).

The objectives of measure 2.3 of EFF were:

- To enhance the efficiency of operations of firms involved in processing and marketing of fish products;
- To enhance product quality and presentation;
- To improve public health and hygiene conditions over and above what is required by national and/or European legislation;
- To develop and market new products;

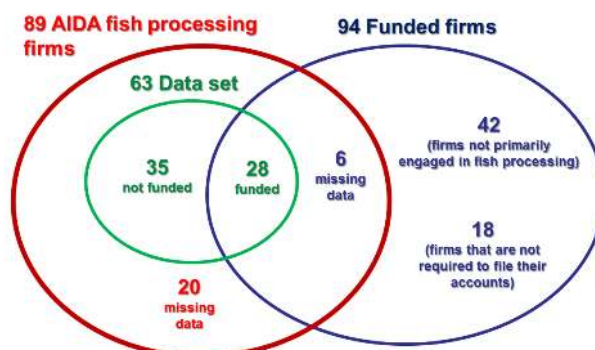


Fig. 1: Dataset scheme

- To improve the management and use of by-products and waste.

The calls have been issued in the years 2009, 2010 and 2011 and in each of them the Sicilian Department of Fisheries has supported investments to increase the production capacity and the modernization of fish-product processing; 94 Sicilian firms has been financed for a total of about 20 million euros of investments.

The data collected on the investments were subsequently linked to the data on the financial statements of the processing firms present in the AIDA database<sup>1</sup>. In particular, we extracted from the AIDA database the balance sheet data, from 2006 to 2015, of all Sicilian transformation firms which declare to mainly carry out fish processing activities (89 firms).

Starting from the 94 funded firms, we found that 42 of them were not primarily engaged in processing activities, they make marginal projects keeping their core business on different activities. In addition, other 18 firms has a legal form that do not require they filling their accounting sheets in an extended format and, therefore, it was not possible for these firms to calculate the index that it's necessary for our analysis.

Looking at the remaining firms (34), we conducted a survey to know the specific data relating to the investments made (type of investment, timing, implementation of investment (Fazio et al. (2016))).

Relating to 89 firms founded in AIDA for 26 of them, unfortunately the data are missing or incomplete and so we had excluded them in our analysis. The remaining 63 firms for which complete data were available are marked as follow: 28 have been financed by EFF while the remaining 35 firms did not made investment using EFF funds. So the data used in our analysis are related to the 63 firms for which we had a complete set of data; 28 of these represent the data of which we want to use to measure the effects of the EFF support for productive investments (treated) and 35 represent the reference data (untreated).

<sup>1</sup> Bureau van Dijk Electronic Publishing. Bureau van Dijk Electronic Publishing - Aida

To quantify the representativeness of this non probabilistic sample, we can state that the 63 firms in our dataset represent about 55% of the Sicilian processing firms, furthermore we check that the 28 treated firms account for about 61% of the total certified investment relating to the measure 2.3 in Sicily.

## 5 Preliminary Results

To evaluate the contribution of funded investment to improving performance, one cannot but consider that projects have an average duration of 3 years but are completed on average over 4 years (65% of projects are completed in 5 years). This means that not all investments generated revenues in the year of subsidia. For this reason, the BP values of the funded firms are considered starting from the first year of the investment revenue.



Fig. 2: BP average trends

Starting from the dataset of 63 firms, it is possible to trace the BP average trend, distinguishing that of the 28 firms funded by that of the 35 not-funded firms. In the graph (see Fig.2), the red line describes the BP average trend of the firms that are funded, starting from the 2009 first call (14 firms) up to that of 2011 (28 firms). The black line, on the other hand, describes the trend of BP related to not-funded firms since 2006 (63) up to 2015 (35 firms).

The average BP shows an improvement in the performance of the funded firms compared to that of non-funded ones.

Furthermore, the effects of two crises in the sector (in 2008 and 2014), observable both in the funded and in the non-funded firms, are less marked in the first ones.

It should be noted that, in the course of 2015, in Italy, the processing sector decrease the business performance; the Sicilian firms that have not been funded decrease their performance more than the sector. On the contrary, 2015 is a growing period for Sicilian funded firms, they start to perform more than the firms they did not invest. The first two call for proposals (2009

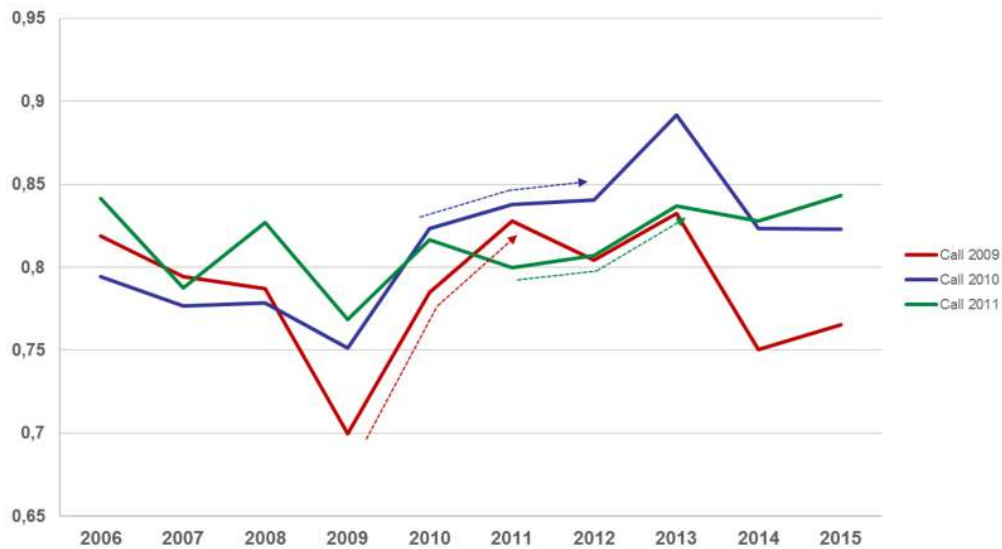


Fig. 3: Average BP index of the funded firms, for each call

and 2010) are those that generate more growth in relative terms of business performance (see 2009-2010, 2010-2011 periods). The differences are increasing. We think that the investments exploit positive economic trend after the 2008 crisis. By adding the impact of 2011 call for proposals (6 firms BP), BP's differences remain stable with some small downturn. The same trend can be observed in firms that do not participate in the initiatives<sup>2</sup>.

Fig.3 shows, in the 2006-2015 period, the average BP index of the funded firms, for each of the three calls (2009, 2010, 2011). The trend of three BPs curves shows a similar growth in income performance during the two years after the implementation of the investment. This result, in first approximation, allowed to the funded firms to consolidate a performance gap along the years.

Finally, Fig.4 shows the average gap between the performances (BP) of the funded firms compared to those not-funded. The values are reported in an abstract time axis, in which the time 0, for each funded firm, corresponds with the year in which the investment generated revenues.

$$sBP_i(t) = \overline{BP_i(t + t_i^*)} - \overline{BP_{unfunded}(t + t_i^*)} \quad (4)$$

<sup>2</sup> Similar trend was noted at the national one (BP estimates on 278 Italian firms).



where  $t_i^*$  = year when the investment of  $i^{\text{th}}$  firm generates sales.

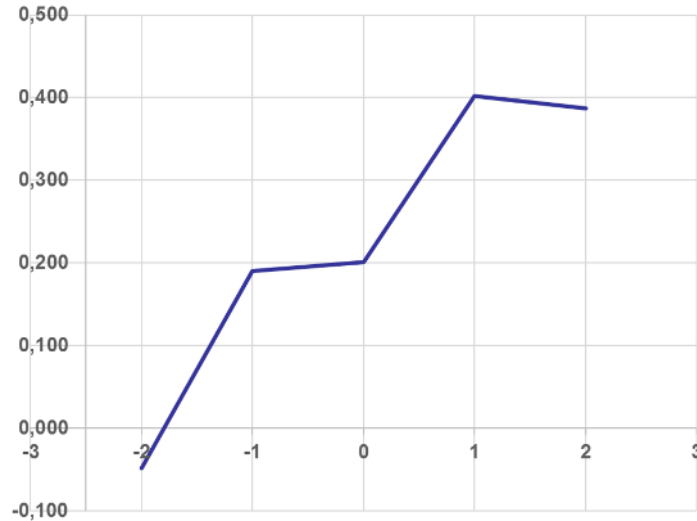


Fig. 4: Average gap between the BP of funded and non-funded firms

This BP index trend suggests that this gap increased after two years compared to the previous two years (from  $t = 0$  to  $t = -2$ ), although the second year shows a slight decline. Two years before ( $t = -2$ ) the gap was negative; this means that the BP of the non-funded firms initially was better than the one of the funded firms, this gap then became positive ( $t = -1$ ) and progressively increased ( $t = +1$ ).

## 6 Conclusion

The results of this empirical analysis, in spite of the fact that it concerns only the processing sector and covers a short time interval, allow to measure the effectiveness of public intervention on innovation in private sectors. The counterfactual analysis, in particular, can be a useful to show to interested firms the potential effects of public support to their investment initiatives. Moreover, the development of a composite indicator, such as the BP, can be useful since it simplifies the comparison between those firms that benefit from public funding and those that do not.

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## A Proposal to estimate the roaming–dog Total in an urban area through a PPSWOR spatial sampling with sample size greater than two.

Ornella Giambalvo · Roberto Sichera

**Abstract** Dogs roaming in urban areas constitute an issue for public order, hygiene and health. Proper planning of actions for health and security control, and allocation of financial funds require the knowledge of the roaming–dog–population size in a given urban area. Unfortunately, a reliable statistical procedure aimed to measure such population is not available yet in literature. This paper presents a simple, reproducible survey sampling procedure to estimate the number of roaming dogs in an urban area through the description of a real study carried out on a restricted area of the city of Palermo, in southern Italy. A sample of areas is drawn by means of a drawn–by–drawn spatial sampling with probabilities proportional to size and without replacement (PPSWOR). As inclusion probabilities are not available in closed form, they are estimated by Monte Carlo approach, which is of simple implementation and permits design–based variance estimation even when first–order inclusion probabilities are unknown.

**Keywords** PPS sampling · design–based variance estimation · inclusion probability · Monte Carlo estimation · roaming dogs

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**Riassunto** *I cani che vagano sul territorio possono rappresentare un rischio per l'uomo in diversi modi: aggressioni, causa di incidenti stradali, rischio igienico. Azioni per il contenimento della crescita di questi gruppi di animali si rendono dunque necessarie. In Italia, la strategia più in uso è quella della cattura, sterilizzazione e successivo rilascio nel territorio dei randagi. Tuttavia, tale strategia ha successo solo se viene applicata all'intera popolazione randagia (Jackman and Rowan, 2007). A tal fine dunque, le autorità sanitarie hanno la necessità di conoscere il numero di randagi presenti sul territorio di competenza. Nonostante in passato siano stati effettuati alcuni tentativi di quantificazione del fenomeno, attualmente in letteratura non si dispone di una metodologia statistica adeguata.*

*In questo articolo presentiamo un'indagine campionaria per la stima del totale di cani randagi tramite uno studio condotto nella prima circoscrizione della città di Palermo. I dati sono stati raccolti su un campione di aree selezionato per mezzo di un campionamento probabilistico con probabilità variabili. Poiché per il disegno campionario adottato le probabilità di inclusione non sono ottenibili in maniera esatta, queste sono state stimate tramite simulazione Monte Carlo e l'algoritmo di Bennett (Fattorini, 2009).*

**Parole Chiave** *Campionamento a probabilità variabili – Stima della varianza – Probabilità di inclusione – Stima Monte Carlo – Cani randagi*

## 1 Introduction

The presence of roaming dogs in urban areas is an important issue that municipalities have to deal with, especially in big cities of Southern Italy where such phenomenon is widespread and represents a source of risk for people and public security, as well as being a concern for public hygiene. In these areas, policy-makers need to undertake actions focused on keeping under control the growth of such population and aimed at reducing its size in the long run. In Italy, the main control technique applied for this purpose is the capture–sterilization–release procedure which, to be effective, needs to be applied to most of the roaming dogs populating a given area (Jackman and Rowan, 2007). Estimating the roaming–dog–population size is thus necessary; however, despite its importance, the size estimation of roaming dogs is a little–covered subject.

Different sources presented figures about this phenomenon, but the methodology used is either omitted (partially or completely) or not statistically sound. One of the attempts made in Italy to find a measure for this phenomenon is a 2006 census arranged by the Italian Ministry of Health (Italian Ministry of Health, 2006). In accordance with this study, in 2006 about 590,000 roaming dogs were evaluated to be in Italy. However, only the dogs that spent some time in public kennels were considered and the estimation/counting procedures are unknown. More data have been released by Italian regions and animal associations, but without relevant results. The *World Society for the Protection of Animals* (WSPA, now *World Animal Protection*) released a report titled *Surveying roaming dog populations: guidelines on methodology*, where a formal procedure to get an estimate of roaming dogs is proposed. WSPA suggests a way to elicit a

sample of sub-areas from the area of interest and find an estimate of the total number of roaming dogs in that territory by means of a simple random sampling.

In this paper, we describe a study carried out in the city of Palermo, Italy, in collaboration with the local health authority. The study consisted in two subsequent ad-hoc surveys and had two aims: first, to formalize a simple and reproducible survey sampling procedure, in order to obtain a statistically reliable estimate and be able to monitor the phenomenon through time in a consistent and comparable way; second, to provide local authorities with an estimate of the roaming-dog-population size for planning proper prevention measures.

Section 2 describes the characteristics of the two surveys and of the data collection procedure. Sampling procedure and estimation methodology are introduced in Section 3, while results are presented in Section 5.

## 2 Features of the survey and data collection

The study started in the beginning of the 2010s with a pilot survey aimed at setting up an effective methodology for the study. We first defined assumptions concerning the distribution of the dogs over territory and their presence along the day considering, together with veterinarians of the local public health authority, their nature and habits.

These assumptions had naturally driven to the choices that defined the sampling design illustrated in this section.

However, during this survey a few data collectors were not accurate in their task, leading to some ambiguous observations that could not be correctly identified and thus to an inflation of the estimates.

As our main focus was to assess the effectiveness of the method, a few years later we set up a new survey with the same characteristics, except for data collection, which we updated with some modifications in order to remove, or at least reduce, non-sampling errors introduced by data collectors' imprecision.

The data collection procedure that we are going to describe is in some aspects similar to the method proposed in WSPA's report (2010).

### 2.1 Data collection settings and procedure

The surveys were carried out in the first district of Palermo, Sicily, a 249.7-hectares-large area, which was divided into 76 sub-areas, each large about 3 hectares and classified in *green-area* (e.g. parks), *open-area* (e.g. parkings and squares) or *other* (e.g. streets), in accordance with its internal pattern.

The number of roaming dogs was observed in a sample of 12 sub-areas. Data collection occurred during the second week of June, due to its stable weather; per each area in the sample, data have been gathered at 13:00 and 20:00 on Monday, Thursday and Sunday. These

choices are in line with World Organization for Animal Health (2010) guidelines and they are aimed to maximize the chances of observing all roaming dogs which dwelt the sample areas.

At the times indicated, each person in charge for data collection visited the assigned location, where they followed a given path. Paths were designed to have approximately equal length among all areas and had been kept fixed over all observations. Data collection sessions lasted at least thirty minutes and the path were completed at least twice throughout each observation session. Data collectors were veterinarians and volunteers of the public local kennel, as well as components of local animal associations. In order to have consistent data entries over all the observations, each person was assigned to one specific area. Although being advised of the importance of collecting data with careful attention to any distinctive trait of the observed dogs and being asked to report all of them in the form, during the first survey, some of the field workers partially or completely neglected this task. The result was a number of observations that were not clearly ascribable to an unique dog.

The second survey was carried out following the same protocol, the only addition made to this procedure was taking a photo of the observed roaming dogs, made possible by the larger diffusion of devices capable of taking pictures of sufficient quality.

## 2.2 Data collection form

In both surveys, each data collector received six forms to fill in with observed information, one per each observation time.

The form used in the first survey included information about gender, size and health conditions (good, bad) of the dogs observed, as well as a section for the observer to write down any other significant information he would have found. Because the last point had been quite neglected, some changes were implemented in the second survey. Dog coat colour, a field to indicate whether or not a picture of the observed dog had been taken and one to write down the picture file name were added to the observed variables. Furthermore, the section dedicated to additional information was reorganised to be easier to fill in and highlighted to be simply reminded to the field workers. In addition, a meeting was held with veterinarians and future field workers in order to explain the details of the data collection procedure.

Applying these simple changes, we achieved a much higher quality of data, with no more issues in identifying different observations of the same dog over different times, and thus improving precision. The form of the second survey is shown in Appendix B.

## 3 Sampling procedure and Estimation

From the population  $U = \{1, \dots, N\}$  of  $N = 76$  areas, a sample  $s = 1, \dots, n$  of  $n = 12$  units has been selected by means of a drawn-by-drawn spatial sampling scheme with selection probabilities proportional to a size variable  $X$  and without replacement (PPSWOR). The selection probability of contiguous units is reduced by means of a parameter  $\beta$ . This design, called

PPS FPDUST, draws a sample according to the following procedure (Barabesi, Fattorini, and Ridolfi, 1997; Fattorini, 2009):

1. Select first unit with probability

$$p_i = \frac{x_i}{\sum_{i \in U} x_i}$$

2. Select  $k$ -th unit,  $k = 2, \dots, n$ , with probability

$$p_{i|i_1, \dots, i_{k-1}} = \begin{cases} \frac{(1-\beta)x_i}{\sum_{i \notin s_k} x_i - \beta \sum_{i \in c(s_k)} x_i}, & i \in c(s_k) \\ \frac{x_i}{\sum_{i \notin s_k} x_i - \beta \sum_{i \in c(s_k)} x_i}, & \text{otherwise} \end{cases} \quad (1)$$

where  $x_i$  are the values of the size variable,  $i = 1, \dots, N$ ,  $s_k = \{i_1, \dots, i_{k-1}\}$  is the set of units selected up to step  $k$  and  $c(s_k)$  is the set of non-sampled units which are contiguous to at least one sampled unit.  $\beta$  is a parameter that modifies selection probabilities for units belonging to  $c(s_k)$  and must take values in the interval  $(-\infty, 1)$  to ensure the existence of the design. When  $\beta = 0$  one obtains the simple random sampling.

In our study, the size variable  $X$  is the walkable area of each unit, that is, the total area excluding buildings and closed spaces such as private parks and parkings (where dogs can not be found). We set  $\beta = 0.5$ , in order to penalize selection of contiguous units, but not too much because sampling close units would have resulted in reduced costs.

Estimation of the number of roaming dogs is performed through the Horvitz-Thompson total estimator (Horvitz and D. J. Thompson, 1952):

$$\hat{Y}_{HT} = \sum_{i \in s} \frac{y_i}{\pi_i}, \quad (2)$$

where  $y_i$  are the values of the variable of interest,  $i = 1, \dots, n$ , in the selected sample  $s$ . The variance of 2 is estimated by

$$\hat{v}(\hat{Y}_{HT}) = \sum_{i \in U} \frac{1 - \pi_i}{\pi_i} y_i^2 + 2 \sum_{i \in U} \sum_{j > i} (\pi_{ij} - \pi_i \pi_j) \frac{y_i y_j}{\pi_i \pi_j} \quad (3)$$

However, estimators (2) and (3) require  $\pi_i$  and  $\pi_{ij}$ , the first and second-order inclusion probabilities, which cannot be directly computed under the sampling scheme adopted.

#### 4 Estimation of inclusion probabilities

An effective way to estimate these quantities is by Monte Carlo simulation (Fattorini, 2006; M. E. Thompson and Wu, 2008), where estimation of inclusion probabilities is carried out by performing  $K$  independent sample drawings from the target population according to the desired



sampling scheme. First-order inclusion probabilities  $\pi_i$  are then estimated as proportion of the number of occurrences of unit  $i$  in the  $K$  trials:

$$\tilde{\pi}_i = \frac{I_i + 1}{K + 1} \quad (4)$$

while the second-order inclusion probabilities  $\pi_{ij}$  are estimated by the proportion of each couple of units  $(i, j)$  in the  $K$  replications

$$\tilde{\pi}_{ij} = \frac{I_{ij} + 1}{K + 1} \quad (5)$$

where  $I_i$  and  $I_{ij}$  are, respectively, the number of occurrences of unit  $i$  and of couple  $(i, j)$  over the  $K$  replications. Both numerator and denominator are incremented by one unit to ensure strict positivity of the estimators.

Estimates of the Total and its variance may now be obtained by substituting (4) and (5) in equation (3):

$$\tilde{Y}_{HT} = \sum_{i=1}^n \frac{y_i}{\tilde{\pi}_i}, \quad (6)$$

$$\tilde{v}(\hat{Y}_{HT}) = \sum_{i \in U} \frac{1 - \tilde{\pi}_i}{\tilde{\pi}_i} y_i^2 + 2 \sum_{i \in U} \sum_{j > i} (\tilde{\pi}_{ij} - \tilde{\pi}_i \tilde{\pi}_j) \frac{y_i y_j}{\tilde{\pi}_i \tilde{\pi}_j}. \quad (7)$$

Fattorini (2006) showed that Monte Carlo estimates converge to the true values as  $K$  increases. Although this approach may be extremely computationally demanding, he showed that a few million replications may be sufficient to obtain reliable estimates.

Moreover, Fattorini (2009) proposed an adaptive algorithm for the estimation of Monte Carlo inclusion probabilities, which runs until a given threshold for the precision of the estimates is reached. Given an arbitrary  $\varepsilon > 0$ , the algorithm ensures that the probability of the relative difference between the Monte Carlo estimate  $\tilde{Y}_{HT}$  and the exact Horvitz-Thompson estimate  $\hat{Y}_{HT}$  is larger than  $\varepsilon$  with probability  $\alpha$ :

$$P \left\{ \frac{|\tilde{Y}_{HT} - \hat{Y}_{HT}|}{\hat{Y}_{HT}} > \varepsilon \right\} = \alpha.$$

Using Bennett inequality (Bennett, 1962), Fattorini, 2009 shows that

$$P \left\{ \frac{|\tilde{Y}_{HT} - \hat{Y}_{HT}|}{\hat{Y}_{HT}} > \varepsilon \right\} \leq 2 \sum_{i \in S} e^{-c(\varepsilon) M \pi_i},$$

where

$$c(\varepsilon) = \left( \frac{\varepsilon}{2 + 2\varepsilon} + 1 \right) \ln \left( \frac{\varepsilon}{2 + 2\varepsilon} + 1 \right) - \frac{\varepsilon}{2 + 2\varepsilon}$$

and  $M > (2 + 2\varepsilon)/(\varepsilon \pi_0)$ , with  $\pi_0 = \min_{i \in s} \pi_i$ . The algorithm takes the name of Bennett algorithm after this last result.

Denote with  $L$  the number of Monte Carlo replicates to perform at each step  $j = 1, 2, \dots$ , and with  $\delta$  the maximum acceptable error for the estimates, such that

$$\frac{|\tilde{Y}_{HT}^j - \hat{Y}_{HT}^{j-1}|}{\hat{Y}_{HT}^{j-1}} < \delta \quad \text{and} \quad \frac{|\tilde{v}^j - \tilde{v}^{j-1}|}{\tilde{v}^{j-1}} < \delta. \quad (8)$$

Moreover, denote with  $K \geq 1$  the minimum acceptable number of consecutive steps that satisfy (8). Then, the Bennet algorithm can be implemented as described below:

1. Choose some values for  $\varepsilon$ ,  $\alpha$ ,  $\delta$ ,  $K$  and  $L$ ;

2. Compute

$$c(\varepsilon) = \left( \frac{\varepsilon}{2 + 2\varepsilon} + 1 \right) \ln \left( \frac{\varepsilon}{2 + 2\varepsilon} + 1 \right) - \frac{\varepsilon}{2 + 2\varepsilon};$$

3. For  $j = 1, 2, \dots$ :

(a) Draw  $L$  Monte Carlo samples from the population  $U$  according to the original sampling scheme and compute the Monte Carlo estimates  $\tilde{\pi}_i$  and  $\tilde{\pi}_{ij}$ ;

(b) Compute  $\tilde{Y}_{HT}$  and  $\tilde{v} \left( \hat{Y}_{HT} \right)$  as in (6) and (7), respectively;

(c) Compute  $\hat{M} = (2 + 2\varepsilon)/(\varepsilon \pi_0)$ , and  $\hat{P} = 2 \sum_{i \in s} e^{-c(\varepsilon) \hat{M} \tilde{\pi}_i}$ , with  $\pi_0 = \min_{i \in s} \tilde{\pi}_i$ ;

(d) Define

$$k(j) = \begin{cases} k(j) + 1, & \text{if } \frac{|\tilde{Y}_{HT}^j - \hat{Y}_{HT}^{j-1}|}{\hat{Y}_{HT}^{j-1}} < \delta \text{ and } \frac{|\tilde{v}^j - \tilde{v}^{j-1}|}{\tilde{v}^{j-1}} < \delta \\ 0, & \text{otherwise} \end{cases}$$

4. If  $k(j) \geq K$ ,  $L \times j \geq \hat{M}$ , and  $\hat{P} \leq \alpha$  stop the algorithm, otherwise return to step 3.

In our study, first and second–order inclusion probabilities were estimated through Bennett algorithm with  $\varepsilon = 0.005$ ,  $\alpha = 0.005$ ,  $\delta = 0.0001$  and  $L = 1000$ .

Computations were performed through the R software and the packages `sampling`<sup>1</sup>, `jipApprox`<sup>1</sup>, `bootstrapFP`<sup>1</sup>, `fpdust`<sup>2</sup>, and `robustHT`<sup>2</sup>. The Bennett algorithm was implemented through an R function, available in Appendix A.

<sup>1</sup> Available on CRAN: <https://cran.r-project.org>

<sup>2</sup> Available on GitHub: <https://github.com/rhobis>

**Table 1** Sample data and estimates for the roaming dogs surveys carried out in the two surveys.

ID	$x_i$	$\tilde{\pi}_i$	$Y_1$	$Y_2$
1	3.17	0.31	5	6
2	2.74	0.29	15	7
3	1.20	0.13	5	1
4	1.13	0.14	3	0
5	1.14	0.14	1	3
6	2.94	0.24	14	9
7	1.46	0.16	1	2
8	2.07	0.22	6	4
9	1.07	0.12	36	13
10	2.66	0.20	8	2
11	1.28	0.15	6	5
12	1.14	0.12	12	1
$\tilde{Y}_{HT}$			700	300
$\sqrt{\tilde{v}(\hat{Y}_{HT})}$			227.5	81.8

## 5 Results

Table 1 presents sample data for the two studies. The table reports the unit ID, the values  $x_i$  of the size measure  $X$  (the walkable area of each unit), the Monte Carlo inclusion probabilities  $\tilde{\pi}_i$ , and the observed number of roaming dogs in the two surveys. The two last rows of Table 1 show the estimates of the Horvitz–Thompson total and of its standard error.

It can be seen that the number of observed dogs in the first survey presents some values that are noticeably higher than others, in particular unit 9. As we mentioned earlier, indeed, the first study was affected by errors during data collection, which nonetheless seem to have been successfully reduced in the second survey by the modifications applied to the data collection form. In fact, besides a general reduction in the presence of roaming dogs, which was likely caused by the interventions of local health authorities, the observed values seem more regular. Unit 9 still exhibits an unusually high value, however it is now much closer to the general distribution of the observations. By analysing data collection forms it seems to be a correct outlier, probably due to a particular concentration of dogs in that area.

The estimated total number of roaming dogs in the first district of Palermo, Italy, more than halved in the four–year–long period between the two studies. The reduction appears too large to be due only to outliers. It seems that the interventions made by the local health authorities to stop the spread of the dog population were effective.

**Table 2** Sample data and estimates for the roaming dogs surveys, considering a reduced sample with area “3c” excluded.

ID	$x_i$	$\tilde{\pi}_i$	$Y_1$	$Y_2$
1	3.17	0.29	5	6
2	2.74	0.27	15	7
3	1.20	0.12	5	1
4	1.13	0.12	3	0
5	1.14	0.12	1	3
6	2.94	0.22	14	9
7	1.46	0.15	1	2
8	2.07	0.20	6	4
10	2.66	0.18	8	2
11	1.28	0.13	6	5
12	1.14	0.11	12	1
$\tilde{Y}_{HT}$			444	212
$\sqrt{\tilde{v}(\hat{Y}_{HT})}$			68.9	28.6

### 5.0.1 Correction for non-sampling errors

As mentioned in Section 2.1, during the first survey some observations were collected poorly, which caused a number of dogs not to be clearly identifiable among different observations on different data collection times. Most of such imprecisions concentrated in one single area, labelled as “3c”, which was very likely to host a much lower number of dogs than the one obtained by the data collection forms. In the particular case of area “3c”, we isolated some groups of observations that likely referred to the same dog, but due to said lack of precision, we could not unequivocally identify them, so that the observed roaming dogs amounted to 36.

A closer inspection to area “3c” shows that, in spite of being the smallest area in the sample, it accounts for the highest number of observations in both studies. This high concentration of dogs may be influenced by geographical reasons such as its proximity to a park and to the sea, an unusual availability of food or other causes. The estimates on obtained on the reduced sample where area “3c” is excluded are reported in Table 2, and show that even in this scenario the estimated number of roaming dogs for the first survey is twice as much as the estimate for the second one.

## 6 Conclusions

The widespread of roaming-dog populations in urban areas is an important issue for local administrations. Despite being essential for a proper planning of health and security actions, no

reliable and reproducible procedure for the estimation of such phenomenon have been adopted yet.

With this study we have proposed a first attempt to define a simple, reproducible survey sampling procedure to estimate the total of roaming dogs on an urban area. The procedure proposed was first implemented through a pilot survey on a reduced portion of the city of Palermo, Italy. Some imprecisions in data collection were identified, so a few years later the study was replicated with same characteristics and an enhanced data collection form.

A sample of sub-areas from the first district of Palermo has been drawn by means of a drawn-by-drawn spatial sampling with selection probabilities proportional to a size variable. For this sampling design exact inclusion probabilities are not available, however they can be easily estimated through Monte Carlo simulation and the Bennett algorithm.

Results appeared satisfactory to the local health authorities, who found the estimates to be close to their expectations. A reduction in the estimated size of the roaming-dog population was registered over the time period between the two studies. This was expected due to the interventions promoted by the health authority after the results of the first survey.

However, further studies are required to improve the efficiency of the survey, for example by defining stratification variables and better size measures that better capture the nature of the phenomenon. Also, more recent spatial sampling designs might be employed, such as the *doubly balanced spatial sampling* (Grafström and Tillé, 2012). More work is also needed to extend the survey to larger areas; this could be done, depending on available human and financial resources, either by including all the city districts in the study or by means of a two-stage design with districts as primary units and their sub-areas as second-stage units.

## A R function for the Bennett algorithm

The R function written to perform the Bennett algorithm is reported below. It requires package `jipApprox`, available on CRAN. The input objects required are the vectors of sample values of the target and auxiliary variables, a vector with the indices of sampled units, the sampling design that produced the original sampling, a list with the arguments to pass to the sampling design function and the values of  $L$ ,  $K$ ,  $\delta$ ,  $\epsilon$  and  $\alpha$ .

```
bennet <- function(y, x, sample_labels, design, design_pars=NULL, K=2,
                  delta=0.001, eps=0.1, alpha=0.1 ){
  n <- length(y)
  k <- 0
  i <- 0
  P <- 100
  M <- Inf
  occurrences <- matrix(1, n, n)
  ce <- (eps/(2+2*eps) + 1) * log( eps/(2+2*eps) + 1 ) - eps/(2+2*eps)

  while( k<K | L*i<M | P>alpha ){
    i <- i+1
    occurrences <- (occurrences - 1) +
      (L+1)*jipApprox::jip_MonteCarlo(x, n, replications = L, design,
      sample_labels, seed = NULL, as_data_frame = FALSE,
      design_pars, progress_bar = FALSE )

    pikl <- occurrences/(L*i+1)
    pik <- diag(pikl)
    ht <- drop(crossprod(y, 1/pik)) # Horvitz-Thompson total estimator
    yy <- outer(y,y)
    pp <- 1/outer(pik, pik) - 1/pikl
    vv <- sum(yy*pp) # Horvitz-Thompson variance estimator
    pi0 <- min(pik)
    M <- 16*log(2/alpha)*eps^(-2)/(pi0)
    P <- 2 * sum( exp(-ce * M * pik))
    if( i>1 ){
      unbiasedness <- abs(ht - ht0)/ht0 < delta
      precision <- abs(vv - vv0)/vv0 < delta
      k <- ifelse( unbiasedness & precision, k+1, 0)
    }
    ht0 <- ht
    vv0 <- vv
  }

  return( list( replicates = L*i, k = k, tot = ht, var = vv, probs = pikl ) )
}
```

## B Data collection form

Figures 1 and 2 show the form used to collect data in the second survey.

*Compilare in stampatello*

Rilevatore: Nome _____ Cognome _____	Data: _____ Ora inizio: _____ Ora fine: _____
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Sede Rilevazione: \_\_\_\_\_ 1B \_\_\_\_\_

Presenza rifiuti 'liberi'  SÌ  NO

Condizioni meteorologiche \_\_\_\_\_

	Taglia	Sesso	Stato di Salute	Colore	Segni particolari (se presenti, specificare sul retro)	Foto
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2	<input type="checkbox"/> P <input type="checkbox"/> M <input type="checkbox"/> G	<input type="checkbox"/> M <input type="checkbox"/> F <input type="checkbox"/> NS	<input type="checkbox"/> S <input type="checkbox"/> M <input type="checkbox"/> NS	<input type="checkbox"/> N <input type="checkbox"/> B <input type="checkbox"/> M <input type="checkbox"/> Altro _____	<input type="checkbox"/> Sì <input type="checkbox"/> No	<input type="checkbox"/> No <input type="checkbox"/> Sì _____
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Fig. 1 Data collection form used in the second survey - front

<p><b>Legenda</b></p> <p>Taglia: P = piccolo, M = medio, G = grande;</p> <p>Sesso: M = maschio, F = femmina, NS = non so;</p> <p>Stato di salute: S = sano, M = malato, NS = non so</p> <p>Colore: N = nero, B = bianco, M = marrone, Altro;</p> <p>Età: A = adulto, C = cucciolo;</p> <p>Segni particolari: qualsiasi informazione aggiuntiva (razza, microchip, ... );</p> <p>Foto: Specificare se è stata scattata una foto o meno. In caso affermativo, inserire il nome del file nello spazio apposito accanto al campo "SI".</p>	<p><b>Segni particolari:</b></p> <p>1. _____</p> <p>2. _____</p> <p>3. _____</p> <p>4. _____</p> <p>5. _____</p> <p>6. _____</p> <p>7. _____</p> <p>8. _____</p> <p>9. _____</p> <p>10. _____</p> <p>11. _____</p> <p>12. _____</p> <p>13. _____</p> <p>14. _____</p> <p>15. _____</p> <p>16. _____</p> <p>17. _____</p> <p>18. _____</p> <p>19. _____</p>
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Fig. 2 Data collection form used in the second survey - back



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## Financial distress and real economic activity in Lithuania: a Granger causality test based on MF-VAR

Ieva Mikaliunaite · Andrea Cipollini

**Abstract** In this study we, first, extend the monthly Financial Stress Index (FSI) for Lithuania computed by ECB (see Duprey et al. (2017)) to a high-frequency (daily) horizon and we also include the banking sector among its constituents (beyond bond, equity, foreign exchange markets). The empirical results suggest no evidence of Granger causality between the monthly FSI index (developed by Duprey et al. (2017)) and monthly industrial production growth. On the contrary, a Granger causality test applied to a VAR using mixed frequency data characterised by a large mismatch in sampling frequencies of the series involved (i.e. daily vs monthly), suggests that the daily Lithuanian FSI has a predictive power for monthly Lithuanian IP growth for the full sample period (October 2001 – December 2016), but not vice versa. Full sample results are confirmed by rolling-window analysis.

**Riassunto** *In questo studio, in primo luogo, estendiamo l'indice mensile di stress finanziario (FSI) per la Lituania calcolato dalla BCE (cfr. Duprey et al. (2017)) ad un orizzonte ad alta frequenza (giornaliero) e includiamo anche il settore bancario tra i suoi costituenti (oltre i mercati obbligazionari, azionari, dei cambi). I risultati empirici non suggeriscono alcuna evidenza di causalità di Granger tra l'indice FSI mensile (sviluppato da Duprey et al. (2017)) e la crescita mensile della produzione industriale. Al contrario, un test di causalità di Granger applicato a un VAR utilizzando dati a frequenza mista caratterizzati da una grande discrepanza nelle frequenze di campionamento della serie coinvolte (cioè giornaliero vs mensile), suggerisce che l'FSI lituano giornaliero ha un potere predittivo per la crescita mensile della produzione industriale lituana*

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per l'intero periodo di campionamento (ottobre 2001 - dicembre 2016), ma non viceversa. I risultati completi del campione sono confermati dall'analisi rolling-window.

**Parole chiave** Granger Causality - Financial Stress Index - Mixed Frequency Data - MIDAS

## 1 Introduction

Measuring financial stress has become more prominent since the global financial crisis. Central banks and international organizations have constructed financial stress indexes (FSI) in order to detect signs of financial stress in the whole financial system and to monitor the state of financial stability. Recently, European Central Bank has introduced a monthly Country-Level Index of Financial Stress (CLIFS) for each of the 27 European Union countries (Duprey et al. (2017)), including Lithuania.<sup>1</sup> This index is constructed by aggregating six financial distress measures, representing the uncertainty and sharp corrections in market prices, that covers only three financial market sectors: bond, stock and foreign exchange markets.

In this paper, first, we seek to improve a monthly Country-Level Index of Financial Stress (CLIFS) for Lithuania (by Duprey et al. (2017)) along two dimensions. First, we extend a monthly ECB financial stress index to a high frequency (*daily*) horizon and, then, by arguing an important role played by Scandinavian commercial banks in the Lithuanian financial sector development, we include the banking sector among its constituents (beyond bond, equity, foreign exchange markets).<sup>2</sup> More specifically, Lithuanian financial sector is dominated by Scandinavian-owned commercial banks. The three largest banks in Lithuania – SEB, Swedbank and DnB – to a significant extent have contributed to the Lithuanian economic growth over the 2000-2007 period.<sup>3</sup> In particular, the growth was fuelled by cheap credit provided by the banks that drove up domestic demand and led to the formation of a 'bubble' in the Lithuanian real estate market. In 2009 the domestic real estate 'bubble' burst and the global financial crisis have led Lithuania into the biggest recession since the independence period. Gross Domestic Product of Lithuania fell -15% in 2009 compared to previous year.<sup>4</sup>

In the second step of the analysis, I contribute to empirical literature exploring the linkages between financial stress and real economic activity. Some studies have recently focused on fi-

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<sup>1</sup> Financial stress indexes were introduced for US (Hakkio et al. (2009); Kliesen et al. (2010); Brave and Butters (2011); Oet et al. (2011)), Canada (Illing and Liu (2006)), major advanced and emerging counties (Cardarelli et al. (2011); Balakrishnan et al. (2011), respectively) and Eurozone as a whole (Hollo et al. (2012) among others.

<sup>2</sup> Also the Bank of England paper by Chatterjee et al. (2017) introduce a FSI for the United Kingdom by extending the CLIFS index by Duprey et al. (2017). The authors incorporate three additional sub-indexes that represent stress in corporate bond, money and housing markets.

<sup>3</sup> Since 2017 the Baltic operations of *DnB* and *Nordea* banks were merged to a new bank - *Luminor*.

<sup>4</sup> While we emphasize the dependence of the Lithuanian financial system from foreign banks, a recent study by Rubio and Comunale (2018) emphasize the vulnerability of the Lithuanian housing markets to Euro area common shock, given that Lithuania has variable-rate mortgages and a higher LTV cap than its European partners.

financial uncertainty as a possible driver of the US business cycle. More specifically, the study of Bloom (2009) obtain an indicator of financial uncertainty by aggregating firm specific financial uncertainty and assess its impact on real economic activity (employment and industrial production). Ludvigson et al. (2015) extract financial uncertainty as a latent variable from a dynamic factor model fitted to a large dataset of financial time series and they assess the impact on real economic activity, proxied by log of real industrial production. Gilchrist et al. (2014) provide a micro and macro based analysis showing that financial frictions are an important part of the mechanism through which uncertainty shocks affect the economy. The authors at macro-level, using a structural vector autoregressive (SVAR) model assess the interactions between uncertainty, credit spreads, and economic activity. The results show that the interaction between financial frictions (proxied by credit spreads) and uncertainty are important to assess how fluctuations in the latter are propagated to the real economy. Unanticipated increases in uncertainty imply a rise in credit spreads, leading to a decline in real GDP that is driven primarily by the protracted drop in the investment component of aggregate spending. In contrast, shocks to financial disturbances (orthogonal to credit spreads) have a large effect on economic activity.

Moreover, a number of empirical studies find that an increase in financial stress has an adverse impact on the overall economic activity. Hakkio et al. (2009) show that an increase in financial stress leads to persistent business cycle downturns. More recently, Chau and Deesomsak (2014) show that the lagged values of financial distress have a significant predictive power for the overall U.S. economic activity. As for the Eurozone, Hollo et al. (2012) find that an increase in the financial distress, proxied by a CISS index, leads to a collapse in industrial production (only for values of the index above a threshold). More recently, Kremer (2016) shows that the CISS index Granger causes EU real GDP growth.

While the aforementioned studies are based on a common frequency dataset, in this paper, we investigate a causal relationship between a *daily* financial stress index for Lithuania and a *monthly* Lithuanian industrial production growth. For this purpose, we use a Granger (non-) causality test applied to a mixed-frequency VAR. As argued by Ghysels et al. (2016), the use of mixed-frequency data allows a more accurate analysis of the causal patterns than a test based on traditional common-frequency data. In addition, given that the mixed-frequency VAR is characterised by a large mismatch in frequencies of the series involved (e.g. daily vs monthly), we apply the Granger causality test developed by Götz et al. (2016) and by Ghysels et al. (2018).

Our findings are in line with Cardarelli et al. (2011) suggesting that banking sector stress tends to be associated with larger negative IP growth, than stress episodes related only with bond, equity and foreign exchange sectors. More specifically, in a common-frequency framework we find that the inclusion of the banking sector related stress in the financial stress index for Lithuania provides more information about the future path of IP growth in Lithuania. Finally, we show that a proposed *daily* financial stress index for Lithuania is a better predictor for a future path of a monthly industrial production growth than a *monthly* CLIFS index of ECB.

Our study is structured as follows. Section 2 describes the recent stylized facts about the Lithuanian financial system and the real economic activity. Section 3 discusses the empirical literature on Financial Stress Index. Section 4 describes our contribution to the construction of FSI for Lithuania. Section 5 describes the Granger causality test based on the MF-VAR. Section 6 discusses the empirical evidence and section 7 concludes.

## 2 Stylized Facts for Lithuania

The development of the Lithuanian financial system over the period 2001-2016, measured by financial system's asset-to-GDP ratio, is shown in Figure 1.<sup>5</sup> The financial system's growth (from 35.7% of GDP in 2001 to 84.5% of GDP in 2016) was mainly driven by the banking sector expansion. In fact, the asset-to-GDP ratio of the banking sector increased from 31.4% in 2001 to 66.7% in 2016.

In total, there are six banks and eight foreign bank branches operating in Lithuanian banking sector. Figure 2 shows that the Lithuanian banking sector is dominated by three Scandinavian-owned commercial banks: Swedish *SEB* bank and *Swedbank*, and Norwegian *DnB* bank. In particular, the assets of the three Scandinavian banks constitute around 73% of the total banking sector assets in 2016. Due to the high concentration in the Lithuanian banking sector the three major banks produce a massive systemic effect on the Lithuanian financial sector.

In the eight-year period from 2000 to 2007 the Lithuanian economy experienced one of the highest economic growth rates within the European Union. As suggested by Kuodis et al. (2009), the growth was fuelled by easy accesses to cheap credit provided by the large Scandinavian-owned commercial banks. On the other hand, the cheap credit and high income expectations gave a strong boost to the construction sector, which led to a formation of a "bubble" in the Lithuanian real estate market.

In 2009 Lithuania went into the biggest recession since the independence period (i.e. since 1990). In the first quarter of 2009 the Lithuanian industrial production fell more than 25% compared to the same period in the previous year.<sup>6</sup> Lithuanian economy was hit by a double-crisis: external one, caused by global financial crisis and internal one, caused by a strong decline in the domestic demand (due to households and firms facing difficulties in meeting their liabilities to credit institutions).

At the end of 2011, the fifth largest Lithuanian bank, *SNORAS* bank, went bankrupt. According to the Bank of Lithuania data, *SNORAS* bank constituted 6.2% of total banking sector loans and 13.0% of deposits. In February 2013, another Lithuanian bank - *Ukio bankas* - went bankrupt. The bank was not a major credit provider, however, it was the fourth in terms of deposit holdings. Nevertheless, the suspension of several institutions did not cause any major turbulence in the financial system.

<sup>5</sup> Source: Bank of Lithuania: <https://www.lb.lt/en/main-indicators-of-banking-sector-activities>

<sup>6</sup> Source: Lithuanian Department of Statistics: <https://www.stat.gov.lt/en>.

At the beginning of 2013, Lithuania's economy bounced back and grew at one of the fastest rates in the EU. However, in the following years the economic growth slowed down due to the uncertainty caused by the Russia-Ukraine conflict and import restriction to Russia in 2014. At the beginning of 2016, the distress in the banking sector increased due to the concerns regarding the real estate sector in Sweden. While we emphasize the dependence of the Lithuanian financial system from foreign banks, a recent study by Rubio and Comunale (2018) emphasize the vulnerability of the Lithuanian housing markets to Euro area common shock, given that Lithuania has variable-rate mortgages and a higher LTV cap than its European partners.

### 3 Financial Stress Index

Since the start of the global financial crisis a number of studies have developed indices of financial stress (FSI) which are used to measure the vulnerabilities in the financial system. The first study is the one by Illing and Liu (2006) introducing a FSI for the Canadian financial system combining (through principal component analysis) information on 11 financial market series representative of the banking, foreign exchange, debt and equity markets. The IMF study by Cardarelli et al. (2011) introduces FSIs for 17 advanced economies. Through variance-equal weighting method, the authors combine information on three financial market segments: banking, securities markets and foreign currency.<sup>7</sup> Similarly, the IMF study by Balakrishnan et al. (2011) uses the methodology of Cardarelli et al. (2011) to construct a financial stress index for emerging countries.

As for the the US, the first study to provide an index monitoring stress in the financial markets is the Kansas City FSI developed by Hakkio et al. (2009).<sup>8</sup> The authors use a principal component analysis to combine 11 indicators, representing the key features of financial stress in the US financial system, into an overall index. Kliesen et al. (2010) propose a St. Louis Fed Financial Stress Index by using 18 weekly data series.<sup>9</sup> Brave and Butters (2011) introduce the National Financial Conditions Index (NFCI), monitoring the financial conditions in banking sector, money, debt and equity markets.<sup>10</sup> The authors show that the NFCI is useful in forecasting growth in US gross domestic product and business investment from two to four quarters ahead. Finally, another FSI index is the Cleveland Fed's Financial Stress Index, developed by Oet et al. (2011).<sup>11</sup> The index uses daily data collected from four financial market sectors — credit, foreign exchange, equity, and interbank markets, which are aggregated into the composite indicator by applying time-varying credit weights.

<sup>7</sup> By using a variance-equal weighting method each component is computed as a deviation from its mean and weighted by the inverse of its variance (Balakrishnan et al. (2011)).

<sup>8</sup> Chen et al. (2014) examine the link between Kansas City FSI and oil prices. Index is available at: <https://www.kansascityfed.org/research/indicatorsdata/kcfsi>.

<sup>9</sup> Index is available at: <https://fred.stlouisfed.org/series/STLFSI>.

<sup>10</sup> Index is available at: <https://www.chicagofed.org/research/data/nfci/background>.

<sup>11</sup> Nazlioglu et al. (2015) analyse a volatility transmission between oil prices and Cleveland FSI. Index was discontinued in May 2016.

The European Central Bank (ECB) periodically publishes a weekly Composite Indicator for Systemic Stress (CISS), developed by Hollo et al. (2012).<sup>12</sup> The CISS index is constructed by aggregating 15 raw indicators of financial stress capturing the developments in five sectors of the Euro area: the money, foreign exchange, equity, bond and non-bank financial intermediaries securities markets.

The ECB database also provides a monthly Country-Level indicator of financial stress, CLIFS, developed by Duprey et al. (2017) for each Eurozone country, including Lithuania.<sup>13</sup> The methodology for the construction of the CLIFS index is similar to the one suggested by Hollo et al. (2012) for the CISS index. However, the CLIFS captures systemic stress only in three financial market segments: equity, long term bonds and foreign currency markets.<sup>14</sup>

## 4 Construction of Financial Stress Index for Lithuania

In this section we describe the construction of the *daily* financial stress index for Lithuania. More specifically, the construction involves three steps: section 4.1 describes the financial time series selected for each sub-sector; section 4.2 explains the methodology used for the transformation of market specific stress indicators; section 4.3 describes how individual indicators are aggregated into the final index.

### 4.1 Data and market indicators

Our *daily* FSI for Lithuania is constructed by using 12 market specific indicators (see Table 1). Similarly to Duprey et al. (2017), we use:

- a) a Lithuanian stock market index - OMX Vilnius (OMXV) - for the equity market,
- b) a 10-year government bond yields - to monitor stress in the bond market,
- c) and compute a *daily* real effective exchange rate for Lithuania - in order to monitor stress in the foreign exchange market.

Moreover, beyond the three financial markets considered by Duprey et al. (2017), we also consider the stress in a banking sector, which we proxy by the stock prices of the three major banks operating in Lithuania: *Swedbank, DnB and SEB bank*.<sup>15</sup> The construction, data sources and the time spans of indicators are described below.

<sup>12</sup> CISS index is available at: <https://sdw.ecb.europa.eu/browse.do?node=9689686>.

<sup>13</sup> CLIFS indexes are available at: <https://sdw.ecb.europa.eu/browse.do?node=9693347>.

<sup>14</sup> As argued by Duprey et al. (2017), other sectors are not considered because the availability of data capturing stress in 27 countries is limited both in the time and cross-sectional dimension.

<sup>15</sup> Duprey et al. (2017) capture the stress in the banking sector by using the bank stock price indices from Datastream. However, it is not available for Lithuania.

#### 4.1.1 Bond market

To measure a distress in Lithuanian bond market we collect a daily 10-year Lithuanian government bond yields for the period ranging from 01/10/2001 to 30/12/2016. The 10-year Lithuanian government bond yields ( $R10_{LT,\tilde{t}}$ ) in the real terms are given by:

$$rR10_{LT,\tilde{t}} = R10_{LT,\tilde{t}} - \frac{CPI_{LT,t} - CPI_{LT,t-12}}{CPI_{LT,t-12}} \times 100 \quad (1)$$

where  $R10_{LT,\tilde{t}}$  is the nominal 10-year government bond yield and  $CPI_{LT,t}$  is the Consumer Price Index for Lithuania;  $\tilde{t}$  denotes days and  $t$  indicates months. Since the CPI is available only on monthly frequency, we simply interpolate the monthly CPI to a daily frequency. Then, we estimate two components of the bond market sub-index:

(i) *daily realized volatility* ( $VrR10_{LT,\tilde{t}}$ ) obtained from the absolute daily changes in the real 10-year Lithuanian government bond yields ( $rR10_{LT,\tilde{t}}$ ). In line with Duprey et al. (2017) we standardize the changes in the real 10-year Lithuanian government bond yields ( $chrR10_{LT,\tilde{t}}$ ) through a 10 year rolling standard deviation (i.e. the window size is set equal to 2520 working days):

$$\begin{cases} chrR10_{LT,\tilde{t}} = rR10_{LT,\tilde{t}} - rR10_{LT,\tilde{t}-1} \\ chr\widetilde{R10}_{LT,\tilde{t}} = \frac{chrR10_{LT,\tilde{t}}}{\sigma_{chrR10_{LT,\tilde{t},\tilde{t}-10years}}} \\ VrR10_{LT,\tilde{t}} = |chr\widetilde{R10}_{LT,\tilde{t}}| \end{cases} \quad (2)$$

(ii) *cumulative difference* ( $CDIFF_{\tilde{t}}$ ) computed as a maximum increase in Lithuanian real government bond spread over a two-year rolling window (i.e. over the previous  $T = 2$  years). In particular the real government bond spread with respect to Germany ( $rR10_{DE,\tilde{t}}$ ) is given by:<sup>16</sup>

$$\begin{cases} rSpread_{\tilde{t}} = rR10_{LT,\tilde{t}} - rR10_{DE,\tilde{t}} \\ CDIFF_{\tilde{t}} = rSpread_{\tilde{t}} - \min_{i=0,\dots,T}(rSpread_{\tilde{t}-i}) \end{cases} \quad (3)$$

#### 4.1.2 Equity market

The Lithuanian stock market index, OMX Vilnius (OMXV), includes all the stocks listed on the main and secondary lists on the Vilnius Stock Exchange. The stock market index in real terms is given as:<sup>17</sup>

<sup>16</sup> The daily data on Lithuania bond yields is obtained as the difference of the daily spread with German 10 year government bond yield available from *Ycharts*:

[https://ycharts.com/indicators/lithuaniagermany\\_10\\_year\\_bond\\_spread](https://ycharts.com/indicators/lithuaniagermany_10_year_bond_spread), and the daily 10-year German government bond yields available from Bundesbank database. Then, we use the monthly CPI for Lithuania and for Germany, available from OECD to convert the nominal yields into real term.

<sup>17</sup> *Note*: CPI is available only on monthly frequency, therefore, we simply interpolate it to a daily frequency.



$$rOMXV_{\ddot{t}} = \frac{OMXV_{\ddot{t}}}{CPI_{LT,\ddot{t}}} \quad (4)$$

Similarly to the bond market, we follow the suggestion of Duprey et al. (2017) and focus on:

(i) *daily realized volatility* ( $VOMXV_{\ddot{t}}$ ) obtained from the absolute daily log stock market returns:

$$\begin{cases} \ln rOMXV_{\ddot{t}} = \log(rOMXV_{\ddot{t}}) - \log(rOMXV_{\ddot{t}-1}) \\ \ln \widetilde{rOMXV}_{\ddot{t}} = \frac{\ln rOMXV_{\ddot{t}}}{\sigma_{\ln rOMXV_{\ddot{t},\ddot{t}-10years}}} \\ VOMXV_{\ddot{t}} = \left| \ln \widetilde{rOMXV}_{\ddot{t}} \right| \end{cases} \quad (5)$$

where the returns are standardized by using a 10 year rolling window standard deviation.

(ii) *cumulative maximum loss* ( $CMAX_{\ddot{t}}$ ), estimated by comparing the value of  $rOMXV_{\ddot{t}}$  at day  $\ddot{t}$  with its maximum value over the previous  $T$  periods ( $T = 2$  years, 507 days).

$$CMAX_{\ddot{t}} = 1 - \frac{rOMXV_{\ddot{t}}}{\max_{i=0,1,\dots,T}(rOMXV_{\ddot{t}-i})} \quad (6)$$

where the backward rolling window is fixed for the first 2 years (04/01/2000 – 31/12/2001).

#### 4.1.3 Foreign exchange market

The Lithuanian foreign exchange market dynamics is monitored by focusing on the *real effective exchange rate*, REER. However, the Bank of International Settlements (BIS) and the ECB Statistical Data Warehouse (SDW) publish the REER for Lithuania only at low frequencies (monthly, quarterly or annual). Therefore, we construct a *daily* REER.

Unlike the bilateral exchange rate that involves two currencies, the effective exchange rate is an index that describes the strength of a currency relative to a basket of other currencies. In particular, we calculate the REER for Lithuania as the geometric weighted average of bilateral nominal exchange rates of litas vis-à-vis the currency of the major trading partners. The major trading partners are: the whole Eurozone (euro), Estonia (kroon), Latvia (lats), China (yuan renminbi), Czech Republic (koruna), Denmark (krone), Japan (yen), Norway (krone), Poland (złoty), Russia (ruble), Sweden (krona), Turkey (lira), United Kingdom (pound sterling), United States of America (dollar).<sup>18</sup> The nominal bilateral currencies are then converted in purchasing power of Lithuanian consumers by using the country specific consumer price index (CPI) (Schmitz et al., 2013):

$$REER^{\ddot{t}} = \prod_{i=1}^N \left( \frac{e_{LT,i}^{\ddot{t}} CPI_{LT}^{\ddot{t}}}{CPI_i^{\ddot{t}}} \right)^{w_i} \quad (7)$$

<sup>18</sup> Estonia and Latvia joined the Eurozone in 2011 and 2014, respectively.

where  $N$  is the number of major trading partner countries;  $e_{LT,i}^t$  is a bilateral exchange rate of the litas vis--vis the currency of partner country  $i$ ;  $w_i$  is the trade weight assigned to the currency of trading partner; the CPI for Lithuania and for the partner country  $i$  are  $CPI_{LT}^t$  and  $CPI_i^t$  respectively.<sup>19</sup> The weights assigned to the major trading partners are shown in Table 2. The 11 Eurozone countries and other 13 major trading partner countries cover 91.4% of Lithuanian total trade in the period 2008 – 2010. The weights are adjusted considering 91.4% to be the total trade (see second row of Table 2). For the comparison, Figure 3 shows that our *daily* REER (in figure aggregated to monthly frequency) is almost identical to the *monthly* REER from BIS.

Then, similarly to bond and stock market, the stress in foreign exchange market is monitored by measuring the following two components:

(i) *daily realized volatility* ( $VREER_{\tilde{t}}$ ) computed as the absolute value of daily growth rate of real effective exchange rate. We divide the growth rate by a 10 years rolling standard deviation (with the window set equal to 2520 working days):

$$\left\{ \begin{array}{l} \ln REER_{\tilde{t}} = \log(REER_{\tilde{t}}) - \log(REER_{\tilde{t}-1}) \\ \widetilde{\ln REER}_{\tilde{t}} = \frac{\ln REER_{\tilde{t}}}{\sigma_{\ln REER_{\tilde{t},\tilde{t}-10years}}} \\ VREER_{\tilde{t}} = \left| \widetilde{\ln REER}_{\tilde{t}} \right| \end{array} \right. \quad (8)$$

(ii) *cumulative change* (CUMUL) of REER over six months ( $i = 6$  months, or 126 working days):

$$CUMUL_{\tilde{t}} = |REER_{\tilde{t}} - REER_{\tilde{t}-i}| \quad (9)$$

#### 4.1.4 Banking sector

In order to measure the stress in the Lithuanian banking sector, we monitor the stock prices of the three major Scandinavian banks: the Norwegian *DnB* bank and the two Swedish banks – *Swedbank* and *SEB*. In particular, the banking sector sub-index consists of six components. For each of the bank we estimate two components:<sup>20</sup>

(i) *daily realized volatility* of the idiosyncratic part of the bank stock price returns ( $VBKS_{B,\tilde{t}}$ ). The idiosyncratic component ( $\epsilon_{B,\tilde{t}}$ ) is the estimated residual from a regression of the bank specific *real* stock price return ( $\ln BKS_{B,\tilde{t}}$ ) on the *real* total stock market index ( $\ln rSX_{c,\tilde{t}}$ ):

<sup>19</sup> The bilateral exchange rates for litas and its major trading partners are collected from the Bank of Lithuania (BoL); the CPI data is taken from OECD and the trading weights from BIS. *Note:* CPI is available only on monthly frequency, therefore, we simply interpolate it to a daily frequency.

<sup>20</sup> We follow the methodology by Duprey et al. (2017) for the components' construction. However, note that the authors do not include the banking sector in the CLIFS for Lithuania.

$$\left\{ \begin{array}{l} \ln BK S_{B,\tilde{t}} = \log(rBK S_{B,\tilde{t}}) - \log(rBK S_{B,\tilde{t}-1}) \\ \ln BK S_{B,\tilde{t}} = \beta_{B,\tilde{t}} \times \ln rSX_{c,\tilde{t}} + \epsilon_{B,\tilde{t}} \\ \tilde{\epsilon}_{B,\tilde{t}} = \frac{\epsilon_{B,t}}{\sigma_{\epsilon_{B,\tilde{t},\tilde{t}-10years}}} \\ VBK S_{B,\tilde{t}} = |\tilde{\epsilon}_{B,\tilde{t}}| \end{array} \right. \quad (10)$$

where the regression is estimated by using a rolling window of two years (fixed for the first two years). The stock market indexes (indexed by  $c = OMXS30, OBX$ ) of Sweden stock market (OMXS30) and Norwegian stock market (OBX) and bank specific stock prices (indexed by  $B = Swedbank, SEB, DnB$ ) are converted in real terms by using the CPI for the related countries, respectively, as:  $\frac{SX_{c,\tilde{t}}}{CPI_{\tilde{t}}}$  and  $\frac{BK S_{B,\tilde{t}}}{CPI_{\tilde{t}}}$ .<sup>21</sup>

(ii) *cumulative maximum loss* of bank stock prices ( $CMAXB_B$ ) for each bank is estimated by comparing the value of  $rBK S_B$  at time  $\tilde{t}$  with its maximum value over the previous  $T$  periods ( $T = 2$  years, 502 working days):

$$CBK S_{B,\tilde{t}} = 1 - \frac{rBK S_{B,\tilde{t}}}{\max_{i=0,1,\dots,T}(rBK S_{B,\tilde{t}-i})} \quad (11)$$

#### 4.2 Transformation of raw stress indicators

In order to aggregate the twelve individual stress indicators into a single financial stress index, firstly, we need to standardize each indicator to have a common unit. Following Hollo et al. (2012) and Duprey et al. (2017), the standardization of stress indicators is based on empirical cumulative distribution function (CDF). This method of standardization consists in converting the six financial stress indicators into new series which are unit-free and ranging between 0 and 1. By this procedure, in the first step, the values of individual stress indicator are ranked and then divided by the total number of observations ( $n$ ). The rank of 1 is assigned to the minimum value in the sample and  $n$  to a maximum.

The empirical CDF is computed as:

$$z_n = F_n(x_n) = \begin{cases} \frac{r}{n} & \text{for } x_{[r]} \leq x_t \leq x_{[r+1]} \\ 1 & \text{for } x_n \geq x_{[n]} \end{cases} \quad (12)$$

<sup>21</sup> The OMXS30 is a stock market index for the Stockholm Stock Exchange that consists of the 30 most traded stock classes (including SEB bank and Swedbank stocks). The OBX Index is a stock market index which lists twenty-five most liquid companies (including DnB bank) of the Oslo Stock Exchange in Norway. The data on *Swedbank* and *SEB bank* stock prices as well as OMXS30 index are from *NASDAQ database*. The data on *DnB* bank stock prices is collected from *DnB database* and the OBX index from *Oslo Bors database*. *Note:* CPI is available only on monthly frequency, therefore, we simply interpolate it to a daily frequency.

where  $r = \{1, 2, \dots, n-1\}$  is a rank number,  $n$  the total number of observations in the sample.<sup>22</sup> The CDF is computed over an initial window of 10 years, after this period, the transformation is applied recursively over expanding samples with one new observation added at a time (keeping the ranks of previous observations fixed).

### 4.3 Aggregation

Once the twelve stress indicators have been transformed, we aggregate them into the final FSI. The aggregation consists in two steps. In the first step, the transformed individual stress indicators capturing stress in a specific financial market are combined (by arithmetic average) to obtain four sub-indexes: the bond market sub-index ( $S_{Bond}$ ), the stock market sub-index ( $S_{Eq}$ ), the foreign exchange market sub-index ( $S_{FX}$ ) and the banking sector sub-index ( $S_{Bank}$ ):

$$\left\{ \begin{array}{l} S_{Bond,\bar{i}} = \frac{VrR10_{\bar{i}} + CDIFF_{\bar{i}}}{2} \\ S_{Eq,\bar{i}} = \frac{VOMXV_{\bar{i}} + CMAX_{\bar{i}}}{2} \\ S_{FX,\bar{i}} = \frac{VREER_{\bar{i}} + CUMUL_{\bar{i}}}{2} \\ S_{Bank,\bar{i}} = \frac{VBKS_{Swed,\bar{i}} + CBKS_{Swed,\bar{i}} + VBKS_{SEB,\bar{i}} + CBKS_{SEB,\bar{i}} + VBKS_{DnB,\bar{i}} + CBKS_{DnB,\bar{i}}}{6} \end{array} \right. \quad (13)$$

Once the sub-indices are computed, we aggregate them into the final FSI by using the approach based on the portfolio theory suggested by Hollo et al. (2012) for the CISS index construction and used more recently by Louzis and Vouldis (2013), Johansson and Bonthron (2013) and by Duprey et al. (2017)). Therefore, the FSI for Lithuania is computed as follows:

$$FSI_{\bar{i}} = (w \times s_{\bar{i}}) C_{\bar{i}} (w \times s_{\bar{i}})' \quad (14)$$

where  $s_{\bar{i}} = (S_{Bond,\bar{i}}, S_{Eq,\bar{i}}, S_{FX,\bar{i}}, S_{Bank,\bar{i}})$  is a vector of the sub-indexes,  $C_{\bar{i}}$  is the matrix of time-varying cross-correlation coefficients between the four sub-indexes and  $w$  is a sub-index weight. Similarly to Duprey et al. (2017), we give the same weight to each sub-index ( $w = \frac{1}{4}$ ).<sup>23</sup>

The portfolio based approach allows taking into account the systemic co-movement across the financial market segments through time-varying cross-correlations between the sub-indexes. The stronger is the correlation of financial stress across the sub-indexes, the more weight is attributed to the FSI. The time-varying cross-correlation  $\rho_{i,j,\bar{i}}$  between sub-indexes  $i$  and  $j$  is estimated recursively using the exponentially weighted moving averages (EWMA) method. In particular, the covariances ( $\sigma_{i,j,\bar{i}}$ ) and volatilities ( $\sigma_{i,\bar{i}}^2$ ) are estimated as follows:

<sup>22</sup> If the same value of  $x$  occurs more than once, the rank number assigned to each of the observations is given as the average of rankings involved.

<sup>23</sup> Hollo et al. (2012) estimate the weights of the sub-indexes in the CISS index by using a bivariate linear VAR and, then, by computing the cumulated impulse response of industrial production growth to a one standard deviation shock to a sub-sector index. However, the authors find that the differences between the CISS computed with impulse response based weights and the one with equal weights are not large.

$$\left\{ \begin{array}{l} \sigma_{i,j,\bar{t}} = \lambda\sigma_{i,j,\bar{t}-1} + (1-\lambda)\bar{S}_{i,\bar{t}}\bar{S}_{j,\bar{t}} \\ \sigma_{i,\bar{t}}^2 = \lambda\sigma_{i,\bar{t}-1}^2 + (1-\lambda)\bar{S}_{i,\bar{t}}^2 \\ \rho_{i,j,\bar{t}} = \frac{\sigma_{i,j,\bar{t}}}{\sigma_{i,\bar{t}}\sigma_{j,\bar{t}}} \end{array} \right. \quad (15)$$

$$C_{\bar{t}} = \begin{bmatrix} 1 & \rho_{Eq,Bond,\bar{t}} & \rho_{FX,Eq,\bar{t}} & \rho_{Bank,Eq,\bar{t}} \\ \rho_{Bond,Eq,\bar{t}} & 1 & \rho_{FX,Bond,\bar{t}} & \rho_{Bank,Bond,\bar{t}} \\ \rho_{Bond,FX,\bar{t}} & \rho_{Eq,FX,\bar{t}} & 1 & \rho_{Bank,FX,\bar{t}} \\ \rho_{Bond,Bank,\bar{t}} & \rho_{Eq,Bank,\bar{t}} & \rho_{FX,Bank,\bar{t}} & 1 \end{bmatrix}$$

where  $i, j = \{Bond, Eq, FX, Bank\}$ ,  $i \neq j$ , with  $\bar{S}_{i,\bar{t}} = (S_{i,\bar{t}} - 0.5)$  denoting demeaned sub-indexes obtained by subtracting their *theoretical* median value (i.e. 0.5). In line with Duprey et al. (2017), we keep the smoothing parameter  $\lambda = 0.85$  constant. The initial values for the covariance and the volatilities (for  $\bar{t} = 1$  which is associated with 2/10/2001) are set equal to the corresponding average values over the two years (i.e. the period running from 2/10/2001 to 30/9/2002).

#### 4.4 Daily financial stress index for Lithuania

The evolution the sub-indexes used for Lithuanian financial stress index construction, over the period 2/10/2001 – 30/12/2016, is displayed in Figure 4. Figure 4 shows that the financial distress in bond, equity, foreign exchange and banking sectors reaches the peak during the period of global financial crisis. In particular, the stock market sub-index peaks in October 2008, the foreign exchange sub-index in January 2009, the banking sub-index in March 2009 and bond sub-index in June 2009.

Figure 5 shows the contribution of each sub-index to the overall distress in the Lithuanian financial system. The contribution of each sub-index increases during the global financial crisis (during mid-2007 – mid-2009) and the major contributor is the banking sector. As expected, during the European sovereign debt crisis period (beginning of 2011 – 2012) the bond market sub-index is the main contributing factor to financial stress. It is also worth noting that the foreign exchange sub-index results as the major contributor to the overall stress in Lithuania in 2015. In particular, distress in the Lithuanian foreign exchange market has increased at the end-2014, when the Russian economy was in a downturn due to the fall in the oil prices and the Russia-Ukraine conflict.

Figure 6 shows the time-varying correlations between the four sub-indices, which quantifies the systemic risk of the Lithuanian financial system. The relatively high correlation coefficient between each pair of market sub-indices associated with relatively high values of all sub-indices is observed over the period from December 2008 to September 2009.

The total *daily* financial stress index for Lithuania is presented in Figure 7. Figure 7 shows that the Lithuanian financial system did not experience high levels of financial stress over the

period 2001-2007. However, the index starts to increase at the beginning of 2008 and reaches a peak right after the collapse of the US investment bank Lehman Brothers. Although the financial distress slightly diminishes at the end of 2009, the rising concerns regarding the sustainability of sovereign debt in the some Eurozone countries (Greece and later Italy, among others) leads to high values of the stress index in May 2010 and over September - October 2011. Furthermore, Figure 7 shows that the failure of two domestic banks: *SNORAS* (in November 2011), which was the third largest bank by deposits and the fifth largest by assets and of *Ukio bankas* (in February 2013), did not affect the stability of the entire financial system.

Finally, Figure 8 compares our *daily* FSI with an alternative *monthly* financial stress index for Lithuania by Duprey et al. (2017), which is available at ECB database. Note, that for a more straightforward comparison, for the moment, we aggregate our daily FSI to a monthly frequency. Figure 8 shows that the two indexes peaks during the GFC. However, while our FSI peaks in the beginning of 2009, the ECB index reach the highest stress level in the mid-2009.

## 5 Mixed Frequency Granger (non-) Causality test

There is an important link between financial stress and the real sector. A number of empirical studies find that increase in financial stress, measured by a financial stress index, can produce substantial spillovers and have significant effects on the real economy.<sup>24</sup> Hollo et al. (2012) find that in the high-stress regimes the increase in the EZ financial distress leads to a collapse in industrial production, while in the low-stress regime it does not have any statistically significant impact. More recently, Kremer (2016) shows that the CISS index Granger cause EU real GDP growth. While the aforementioned studies are based on a common low frequency dataset, in this section, I investigate a causal relationship between a *daily* financial stress index for Lithuania (constructed in section 4) and a *monthly* Lithuanian industrial production growth.

### 5.1 Mixed Frequency VAR

Consider two time series sampled at different frequencies: a low-frequency series  $x_L$  and a high-frequency series  $x_H$ . A high-frequency series is observed  $m$  times during a low-frequency period  $t$ . According to Ghysels (2016), the mixed frequency VAR model can deal either with a case of a small  $m$  (e.g. when the series are sampled at quarterly/annual or weekly/daily frequency), or with a case of a large  $m$  (e.g. when the series are sampled at daily/monthly or weekly/quarterly frequency). In this paper, we focus on the large  $m$  case: one series is sampled at *monthly* and the other one at *daily* frequency.

<sup>24</sup> For instance, when financial markets suffer from high distress increased uncertainty about asset value decreases the value of collateral. As the consequence, shocks affecting the creditworthiness lead to increased swings in output. At the same time, economic activity is affected by the fact that bank capital is eroded, which forces banks to deleverage and decrease the lending to businesses.

In MF-VAR all observations of period  $t$  (i.e. high and low frequency observations) are stacked into a column vector by treating the  $m$  observations of the high-frequency series as if they were distinct endogenous variables. Let  $x_H(t, 1)$  be the first high-frequency observation of  $x_H$  in low frequency period  $t$  (e.g. the first daily observation of the month  $t$ ), a  $x_H(t, 2)$  – the second, and  $x_H(t, m)$  – the last one. Consider a high-frequency vector in  $t$ -period as  $[x_H(t, 1), x_H(t, 2), x_H(t, j), \dots, x_H(t, m)]'$ . Then, a mixed frequency vector with one high and one low frequency variable is denoted as  $Z(t) = [x_H(t, 1)', \dots, x_H(t, m)', x_L(t)']'$ , with the dimension  $K \times 1$ , where  $K = m + 1$ .

A reduced-form vector autoregressive model with mixed-frequency data (MF-VAR(p)) is given by:<sup>25</sup>

$$\begin{pmatrix} x_H(t, 1) \\ \vdots \\ x_H(t, m) \\ x_L(t) \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \vdots \\ \mu_m \\ \mu_{m+1} \end{pmatrix} + \sum_{k=1}^p \begin{pmatrix} d_{11,k} & \cdots & d_{1m,k} & c_{1,k} \\ \vdots & \ddots & \vdots & \vdots \\ d_{m1,k} & \cdots & d_{mm,k} & c_{m,k} \\ b_{1,k} & \cdots & b_{m,k} & a_k \end{pmatrix} \begin{pmatrix} x_H(t-k, 1) \\ \vdots \\ x_H(t-k, m) \\ x_L(t-k) \end{pmatrix} + \begin{pmatrix} u_H(t, 1) \\ \vdots \\ u_H(t, m) \\ u_L(t) \end{pmatrix}$$

or

$$Z(t) = \mu + \sum_{k=1}^p \Gamma_k Z(t-k) + u_t \quad (16)$$

The coefficients  $b$ 's and  $c$ 's capture the causality from a high-frequency variable  $x_H$  to the low frequency variable  $x_L$ , and the causality from  $x_L$  to  $x_H$ , respectively. More specifically, testing for Granger (non-) causality implies the following null hypothesis:

– **High-to-low (non-) causality.**  $x_H$  does not Granger cause  $x_L$  if and only if:

$$H_0 : b_{1,k} = \dots = b_{m,k} = 0; \text{ for } k = 1, \dots, p \quad (17)$$

– **Low-to-high (non-) causality.**  $x_L$  does not Granger cause  $x_H$  if and only if:

$$H_0 : c_{1,k} = \dots = c_{m,k} = 0; \text{ for } k = 1, \dots, p \quad (18)$$

## 5.2 Granger causality test

Given that the mixed-frequency VAR in section 5.1 is characterized by a large mismatch in sampling frequencies of the series involved (i.e. daily *vs* monthly), in this section we describe the Granger causality tests that take into account this issue. Götz et al. (2016) develop a test for a *high-to-low* and *low-to-high* Granger causality in a mixed-frequency VAR by using a Wald test. The Wald test is based on the unrestricted MF-VAR in (16). Let  $\hat{\Gamma}$  denote an OLS estimates of the coefficient matrices for the lagged endogenous variables in the MF-VAR (16)

<sup>25</sup> The parameters in  $\Gamma$  can be estimated by using an OLS estimator.

and define  $R$  a matrix that picks the set of coefficients of interest for Granger (non-) causality test i.e.  $Rvec(\hat{\Gamma})$ . Then, the Wald test statistic is constructed as:

$$\hat{\xi}_W = [Rvec(\hat{\Gamma})]'(R\hat{\Omega}R')^{-1}[Rvec(\hat{\Gamma})] \quad (19)$$

with

$$\hat{\Omega} = (W'W)^{-1} \otimes \hat{\Sigma}$$

where  $\hat{\Sigma} = \frac{1}{T_L}\hat{u}'\hat{u}$  is the covariance matrix of the disturbance terms in (16) and  $W$  is the regressor set. However, in a mixed-frequency model with a large  $m$  an asymptotic Wald test may exhibit size distortions when the number of zero restrictions is relatively large, compared to a sample size (Götz et al. (2016); Ghysels et al. (2018)). Therefore, Götz et al. (2016) rely on bootstrap in order to draw an inference based on the Wald test.<sup>26</sup>

Ghysels et al. (2018) propose a *max-test* only for *high-to-low* Granger causality case with a large number of zero restrictions. More specifically, the *max-test* statistic is based on  $pm$  parsimonious regression models:

$$x_L(t) = \mu_i + \sum_{k=1}^p a_{k,i}x_L(t-k) + \beta_i x_H(t-1, m+1-i) + u_{L,i}(t), \quad (20)$$

where index  $i \in \{1, \dots, pm\}$  is in high-frequency terms and the second argument  $(m+1-i)$  of  $x_H$  can be less than 1 (since  $i > m$  occurs when  $p > 1$ ). Each  $i^{th}$  model contains  $p$  low-frequency autoregressive lags of  $x_L$  and only the  $i^{th}$  high-frequency lag of  $x_H$ . We estimate the parsimonious model  $pm$  times. It is important to notice that the  $\beta_i$  in parsimonious models (20) and  $b$ 's in unrestricted model (16) generally are not equivalent. We estimate the parameters in each  $i^{th}$  model by OLS to get  $\hat{\beta}_i = \{\hat{\beta}_1, \dots, \hat{\beta}_{pm}\}$ . Then we formulate a *max-test statistic* as:

$$\hat{\mathcal{T}}_{T_L} = \max_{1 \leq i \leq pm} \{(\sqrt{T_L}\hat{\beta}_i)^2\} \quad (21)$$

where  $T_L$  is a low-frequency sample size. The mixed-frequency *max-test statistics*  $\hat{\mathcal{T}}_{T_L}$  has a non-standard asymptotic distribution under the null hypothesis in (17). Therefore, we follow Ghysels et al. (2018) and rely on a simulation-based p-value.

## 6 Empirical Evidence

### 6.1 Data

We focus on the *daily* Lithuanian FSI (constructed in section 4) and *monthly* industrial production (IP) growth in Lithuania for the sample period running from October 2, 2001 to December

<sup>26</sup> Montecarlo simulations in Götz et al. (2016) show that bootstrap variants of *high-to-low* and *low-to-high* causality tests improve the empirical size.



30, 2016, yielding a sample size of  $T_L = 183$  months. In line with Hollo et al. (2012) and Duprey et al. (2017) we use a year-to-year IP growth estimated as 12th month log-difference. We use a seasonally and working day adjusted data on Lithuanian industrial production, which is available from the Lithuanian Department of Statistics.

Figure 9 plots the data. The figure suggest that Lithuanian economy has experienced a high growth up to the end-2008. With the beginning of the global financial crisis the IP shrank, decreasing for 14 consecutive months (from November 2008 to January 2010), peaking at (minus) -31.4% in April 2009.

The *daily* Lithuanian FSI, constructed in section 4, has a varying number of *daily* observations within each *month*, ranging from 18 to 23 observations. In order to perform a MF Granger causality test, for simplicity, we assume that the maximum amount of *daily* observations that is available in each month throughout the sample is 18 ( $m = 18$ ). More specifically, the *daily* Lithuanian FSI series are modified as follows:

$$FSI_H(t, j) \quad \text{for } j = 1, \dots, 18 \quad (22)$$

where the last  $m(t) - 18$  observations at the end of each month are disregarded (see Götz et al. (2016)).<sup>27</sup> This modification gives us a dataset with  $T_L = 183$  low-frequency observations,  $m = 18$  and  $m \times T_L = 3294$  high-frequency observations. Therefore, when setting the MF-VAR model specification, the stacked vector of endogenous variables has a dimension  $K = 19$ . The Phillips and Perron (1988) test for unit-root suggest that the data are stationary (at 10-percent significance level).<sup>28</sup>

## 6.2 Granger causality tests

To test for Granger causality from the *daily* Lithuanian FSI ( $FSI_H$ ) to *monthly* IP growth in Lithuania ( $IP_L$ ) we focus on the last row of MF-VAR(2) specification in (16):

$$IP_L(t) = \mu_{19} + \sum_{k=1}^2 a_k IP_L(t - k) + \sum_{i=1}^{36} b_i FSI_H(t - 1, 18 + 1 - i) + u_L(t) \quad (23)$$

where we regress the *monthly* IP growth onto a constant ( $\mu_{19}$ ),  $p = 2$  months of lagged low-frequency variable (IP growth),  $pm = 36$  days of lagged high-frequency variable (FSI for Lithuania).<sup>29</sup> The Wald test developed by Götz et al. (2016) consider the unrestricted model described in (16). The model is estimate by using ordinary least squares. The p-values for the Wald test

<sup>27</sup> Note that the  $x_H(t, 1)$  is not necessarily the first day of the month. For example, October 1, 2016 fall on Sunday. Thus, October 3, 2016 is considered as the first observation of the month  $x_H(t, 1)$ .

<sup>28</sup> Results are available upon request.

<sup>29</sup> The model specification is chosen according to the suggestions of Ghysels et al. (2018). More specifically, we perform a Ljung-Box Q-test to test for the absence of serial correlation in residuals of the full regression model eq. (23). The p-values for Q-test are reported in Appendix, Table 5.

for the null hypothesis  $H_0 : b_1 = \dots = b_{36} = 0$  in eq. (17) are computed using 1999 bootstrap replications.<sup>30</sup>

The *max-test* by Ghysels et al. (2018)) is based on *parsimonious* regression models:

$$IP_L(t) = \mu_i + \sum_{k=1}^2 a_{ki} IP_L(t-k) + \beta_i FSI_H(t-1, 18+1-i) + u_{L,i}(t) \quad (24)$$

for  $i = \{1, \dots, 36\}$ , where each  $i^{th}$  model contains  $p = 2$  months of lagged IP growth and only the  $i^{th}$  daily lag of FSI for Lithuania.<sup>31</sup> We estimate the *parsimonious* model 36 times. The number of parameters to estimate in the *parsimonious* regression model is 4 (1+2+1) against 39 (1+2+36) in the *full regression* model in eq.(23).<sup>32</sup> For the robustness check we also try the different model specifications: MF-VAR(1) and MF-VAR(3).

To test for Granger causality from *monthly* IP growth to *daily* FSI for Lithuania, defined as  $H_0 : c_1 = \dots = c_{36} = 0$  in (18), we focus on an unrestricted model in (16) (see last column of the model) and we use the Wald statistics eq. (19) developed by Götz et al. (2016).

## 6.3 Empirical findings

### 6.3.1 Full sample analysis

The full sample results in Table 3 panel (A) show that the *daily* Lithuanian FSI has a predictive power for *monthly* Lithuanian IP growth for the period (October 2001 – December 2016), but not vice versa. More specifically, the p-values suggest that, for any MF-VAR model specification (with lag order ( $p$ ) equal to 1, 2, or 3), there is evidence of unidirectional causality from *daily* Lithuanian FSI to *monthly* IP growth in Lithuania. In fact, while both the *max-test* and the Wald test reject the null hypothesis that FSI does not Granger cause IP growth at 10% significance level, we cannot reject the null hypothesis that IP growth does not Granger cause FSI.

In addition, our analysis is in line with other studies (see Hakkio et al. (2009), among others) which find that an increase in financial stress has an adverse impact on the overall economic activity. In particular, Figure 10 shows that the point estimates of the coefficients  $\beta_i$  for each  $i^{th}$  parsimonious model (eq. 24) used to evaluate the effect of financial stress on economic activity is negative and statistically significant (at 95% confidence interval).

Further, in order to evaluate our index, we compare the *daily* FSI for Lithuania with alternative financial stress indexes. Specifically, we test for Granger causality between *monthly* IP growth in Lithuania and (i) a *daily* FSI for Lithuania, constructed by taking into consideration

<sup>30</sup> For bootstrap, we use a code provided by Götz et al. (2016).

<sup>31</sup> Following Ghysels et al. (2018) p-values are computed based on the robust covariance matrix with 100 000 draws from an approximation to the limit distribution under non-causality.

<sup>32</sup> We estimate 4 parameters in each  $i^{th}$  parsimonious model eq. (24): (i) a constant ( $\alpha_{0i}$ ), (ii) two coefficients related to the lagged IP growth ( $a_{1i}, a_{2i}$ ) and (iii) one coefficient related to the lagged FSI ( $\beta_i$ ).

only three sub-indexes - bond, equity and foreign exchange (excluding banking sub-index), (ii) a *monthly* FSI for Lithuania (composed of 4 sub-sectors: bond, equity, foreign exchange and banking), obtained by averaging the daily FSI to a monthly frequency, and (iii) a *monthly* CLIFS index provided by ECB and developed Duprey et al. (2017), which is composed of only three sub-indexes - bond, equity and foreign exchange.

As for case (i), the p-values in Table 3 panel (B) suggest that a *daily* FSI for Lithuania, constructed by taking into consideration only three sub-indexes - bond, equity and foreign exchange (excluding banking sub-index), is also a good predictor for a *monthly* IP growth in Lithuania. More specifically, for any MF-VAR specification (with lag order equal to 1, 2 or 3) the *daily* FSI (3 sub-indexes) Granger cause a *monthly* IP growth in Lithuania, but not vice versa. Furthermore, the point estimates of the coefficients  $\beta_i$  for each  $i^{th}$  parsimonious model (eq. 24) in Figure 11 shows that an increase in financial stress in equity, bond and foreign exchange sectors leads to a slowdown in IP growth in Lithuania, although the effect is slightly smaller compared to the *daily* FSI that also contains the banking sector related stress sub-index.

As for case (ii), we use a common frequency VAR(1) to test for Granger causality between *monthly* IP growth in Lithuania and a *monthly* FSI for Lithuania (composed of 4 sub-sectors: bond, equity, foreign exchange and banking). The p-values in Table 3 panel (C) suggest a unidirectional causality from a *monthly* FSI to a *monthly* IP growth, since we can reject the null hypothesis of non-causality relying on an asymptotic and a bootstrap version of a Wald test. Moreover, a common frequency regression results in Table 4 panel A show that an increase in financial stress has a negative and statistically significant impact on the IP growth in Lithuania.

As for case (iii), we investigate the causal relationship between the *monthly* CLIFS developed by Duprey et al. (2017) and the *monthly* Lithuanian IP growth series.<sup>33</sup> For this purpose, we use an asymptotic and a bootstrap Wald test for testing bi-directional Granger causality. The full sample results in Table 3 panel (D), based on VAR(2) model, suggest that we cannot reject the null hypothesis of non-causality in both directions. This empirical finding is confirmed by the common frequency regression results in Table 4 panel (B) suggesting that a CLIFS index has a negative impact on IP growth in Lithuania, although the effect is not statistically significant.

To summarize, the empirical findings suggest the importance of including the banking sector into the financial stress index (and the use of a mixed frequency dataset), otherwise the negative causal effect on IP growth would not be detected.

### 6.3.2 Rolling-window analysis

We also assess if there is any evidence of changes in the causality between the *daily* FSI for Lithuania and *monthly* IP growth over the full sample period. For this purpose, we implement a rolling-window Granger causality test, fixing the window size to 84 months (i.e. seven years).<sup>34</sup>

<sup>33</sup> The index is composed of 3 sub-sectors, reflecting the stress in equity, bond and foreign exchange market.

<sup>34</sup> The rolling-window analysis uses a fixed-length window, which moves sequentially from the beginning to the end of the sample period by adding one observation ahead and dropping one from the behind.

This gives a total of 100 sub-samples, where the first sub-sample covers the period from October 2001 to September 2008 and the last sub-sample covers the period from January 2010 to December 2016. In line with the full sample analysis, we use a *max-test* developed by Ghysels et al. (2018) and the Wald test developed by Götz et al. (2016) for each sub-sample.

Figure 12 plots the rolling window p-values for each causality test over the 100 windows (the last observation of each sub-sample period is shown on the horizontal axis). More specifically, Panel A and B show the *max-test* and the Wald test p-values for the null hypothesis that a *daily* FSI does not Granger cause the *monthly* IP growth in Lithuania. The p-values of the Wald test for the causality in the opposite direction are presented in the panel C of Figure 12.

In line with full sample analysis, the results suggest that we cannot reject the null hypothesis that IP growth in Lithuania does not Granger cause the financial distress in Lithuania at 10% significance level. On the contrary, we find that a *daily* financial stress index for Lithuania has a predictive power for *monthly* Lithuanian IP growth (at 10% significance level) for most of the considered sub-samples, according to the *max-test* and to the Wald test (see Panel A – B in Figure 12). In particular, the *max-test* (see panel A) confirms the causality from FSI to IP growth from April 2009 to March 2016, and the Wald test (see panel B) detects a significant causality from the January 2010 to January 2016.<sup>35</sup>

Furthermore, the p-values of a rolling window analysis in Figure 13 panel (A)-(B) suggest that a *daily* FSI for Lithuania, constructed by aggregating only 3 sub-indexes (bond, equity and foreign exchange) is also a good predictor of *monthly* Lithuanian IP growth, since we can reject the null hypothesis of non-causality at 10% significance level in most of the considered sub-samples. Panel C shows that IP growth does not Granger cause financial distress in the sub-samples covering the period from July 2009 to November 2013. Moreover, the p-values in Figure 14 of an asymptotic Wald test implemented for a rolling window analysis suggest a unidirectional causality from *monthly* FSI, composed of 4 sub-indexes (bond, equity, foreign exchange and banking), to *monthly* IP growth, since we can reject the null hypothesis of non-causality in most of the sub-samples (see panel A). In line with the full sample analysis the only case associated with no evidence of causality in both directions is when we focus on the relationship between *monthly* CLIFS index by Duprey et al. (2017) and *monthly* IP growth. More specifically, the rolling window analysis results in Figure 15 suggest no causality between *monthly* CLIFS index by Duprey et al. (2017) and *monthly* IP growth.

## 7 Conclusions

In this paper, first, we construct a *daily* Financial Stress Index (FSI) for Lithuania. In particular, we extend the monthly Financial Stress Index (FSI) for Lithuania, computed by ECB (see Duprey et al. (2017)), to a high-frequency (*daily*) horizon and, given the important role played by a banking sector in the Lithuanian economic development in the recent decade, we include the banking sector among its constituents (beyond bond, equity, foreign exchange markets).

<sup>35</sup> Note that we report the last observation of the sub-sample period.

Moreover, we investigate the causal relationships between the *daily* FSI for Lithuania and *monthly* industrial production growth, using a Granger causality test applied to a mixed-frequency VAR characterised by a large mismatch in sampling frequencies of the series involved (i.e. *daily* vs *monthly*). The empirical findings suggest that the *daily* Lithuanian FSI has a predictive power for *monthly* Lithuanian IP growth for the full sample period (October 2001 – December 2016), but not vice versa. These results are also confirmed by a rolling-window analysis, where we allow the causal relationship to vary over time. Moreover, our analysis is in line with the empirical studies (see Hakkio et al. (2009), among the others) showing that an increase in financial stress has an adverse impact on the overall economic activity. In particular, we show that a banking stress in Lithuania leads to a stronger decline in IP growth.

Finally, we show that our *daily* FSI for Lithuania is a better predictor for monthly industrial production growth than a *monthly* Country-Level Indicator of Financial Stress developed by ECB (Duprey et al. (2017)).

Overall, our findings for Lithuania suggest that the leading indicator properties of an FSI index for Lithuania with respect to industrial production growth can be enhanced if we take into account the banking sector and we use *daily* observations.

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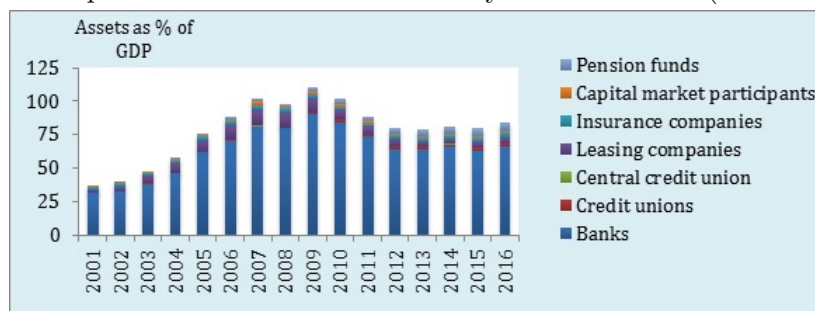
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## A Appendix

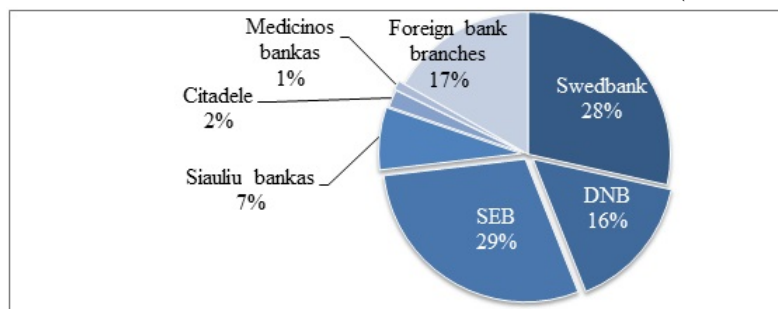
### A.1 Figures: stylized facts for Lithuania

Fig. 1: The development of Lithuanian financial system 2001-2016 (assets as % of GDP)



Source: Bank of Lithuania (<https://www.lb.lt/en/financial-stability#ex-1-1>).

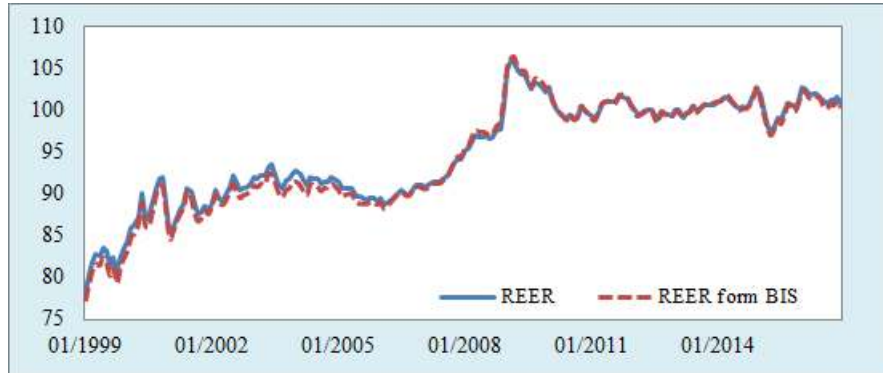
Fig. 2: Lithuanian banking sector structure by assets (end-2016)



Source: Bank of Lithuania (<https://www.lb.lt/en/main-indicators-of-banking-sector-activities>).

## A.2 Figures: FSI for Lithuania

Fig. 3: Our REER in comparison with the REER for Lithuania from BIS



*Notes:* The straight line is the monthly REER index we compute by aggregating daily data. The dotted line is the monthly REER index available from BIS.

Fig. 4: Sub-indexes (2001-2016)

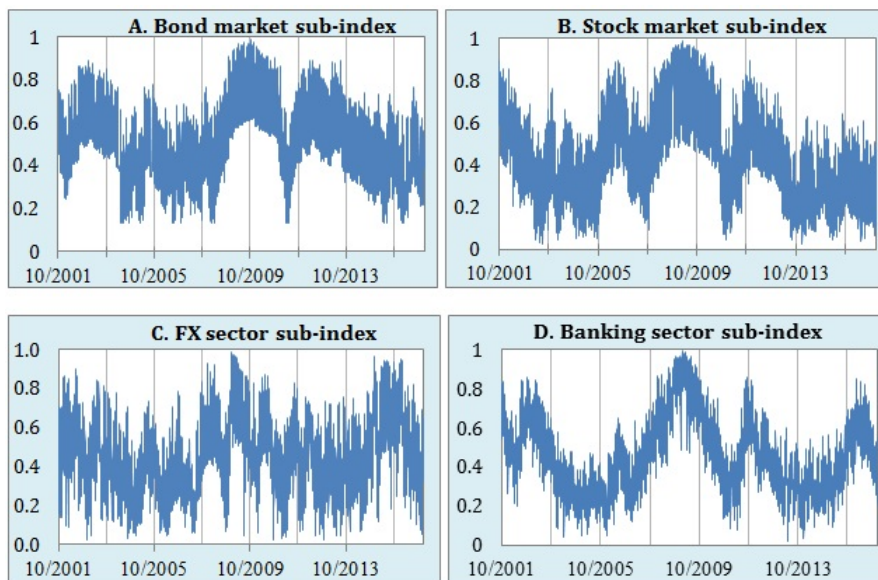




Fig. 5: Contribution of the sub-indexes to the overall FSI

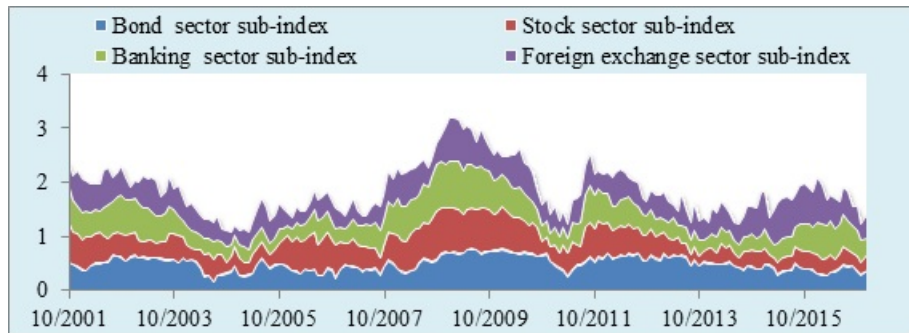
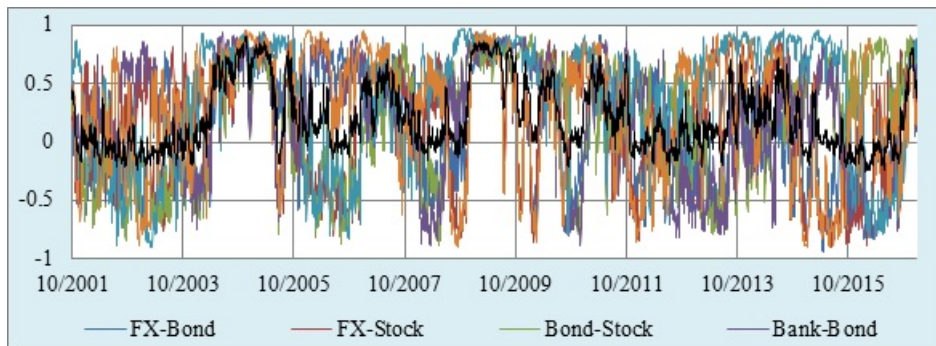
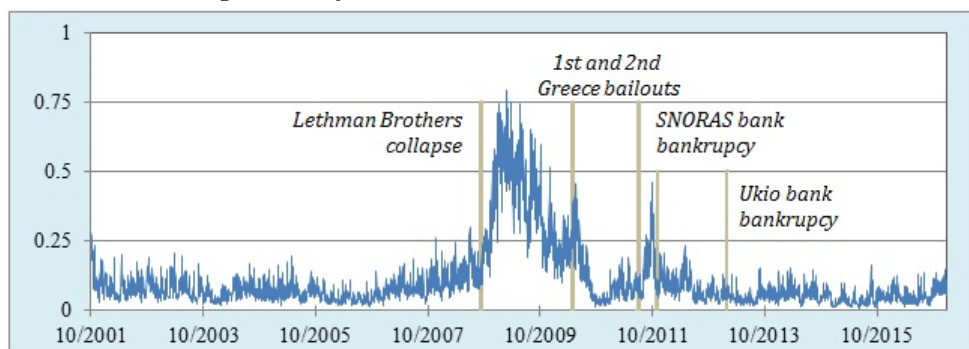


Fig. 6: Time varying cross-correlations between the sub-indexes



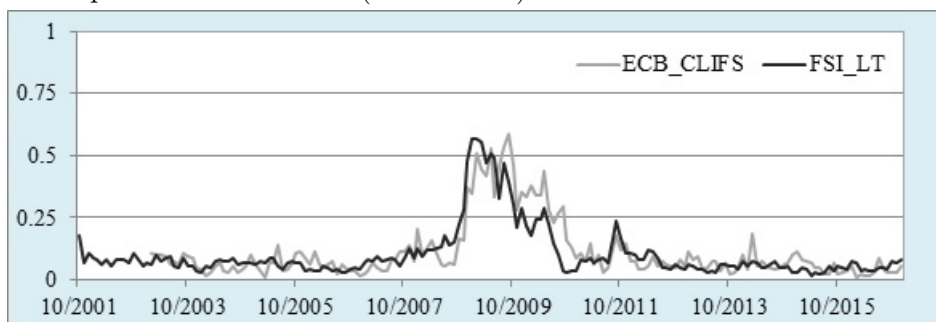
Notes: We use EWMA with smoothing parameter 0.85 (see eq. 15) to estimate the pairwise correlations among sub-sectors.

Fig. 7: Daily financial stress index for Lithuania



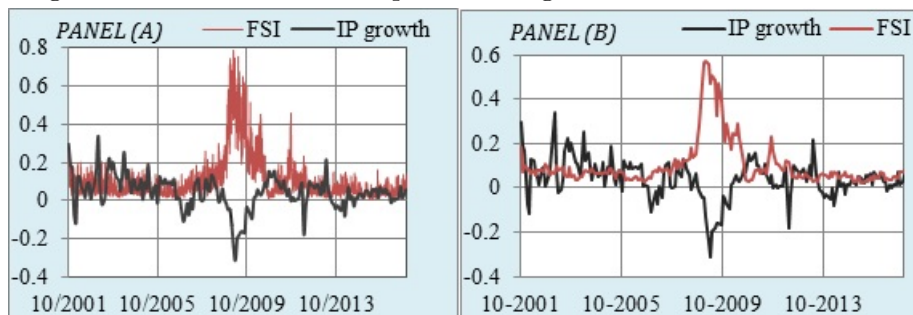
Notes: Bars are associated with the following crisis events: the bankruptcy of US investment bank Lethman Brothers, first and second Greece bailouts, and SNORAS and Ukio banks bankruptcy.

Fig. 8: Comparison between FSI (dark colour) and a CLIFS for Lithuania from ECB



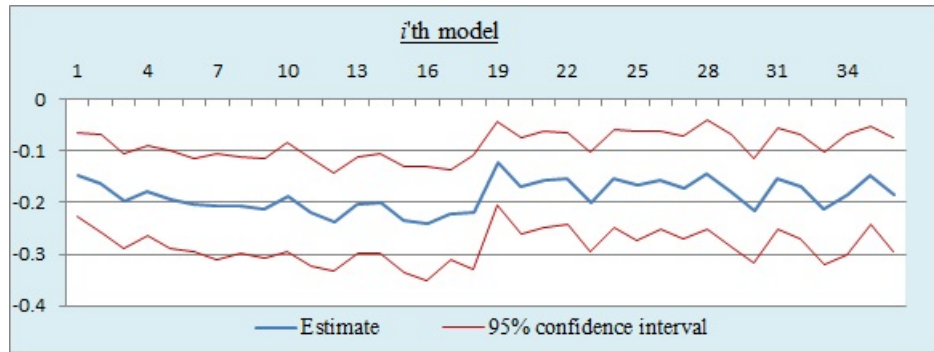
Notes: The bold line is daily Lithuanian FSI aggregated into monthly frequency. The grey line is the monthly Lithuanian CLIFS index available from ECB at: <https://sdw.ecb.europa.eu/browse.do?node=9693347>.

Fig. 9: Lithuanian industrial production growth and FSI for Lithuania

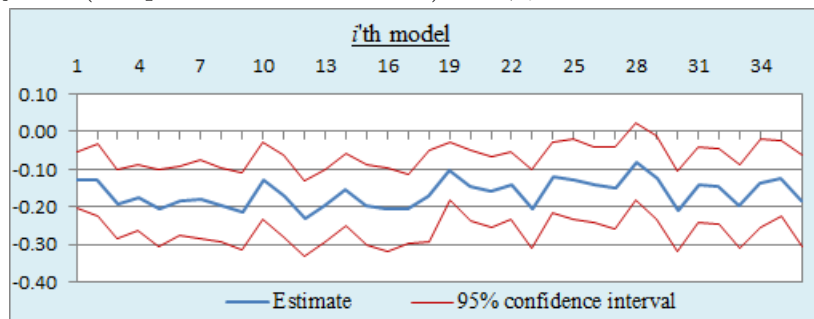


Notes: In PANEL (A) we show the *daily* FSI, while in PANEL (B) the index is aggregated to *monthly* frequency. The IP growth is estimated as 12th month difference in log output, for a period October 2001 - December 2016. IP growth is in black colour and FSI is in red colour.

## A.3 Figures: full sample analysis

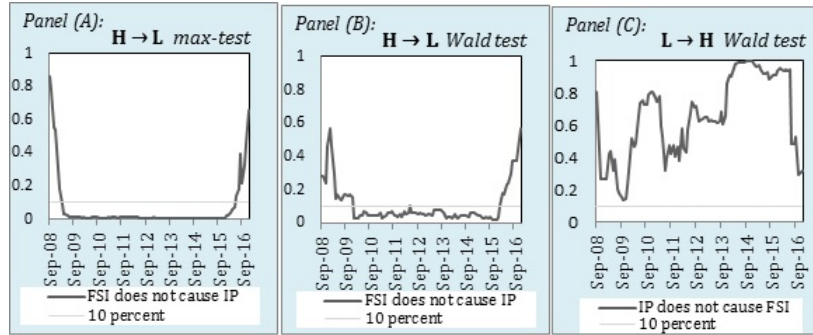
Fig. 10: *Daily* FSI (4 sub-indexes): the  $\beta_i$  coefficient values in each  $i^{th}$  model

Notes: The plot shows the point estimates of the coefficients  $\beta_i$  for each  $i^{th}$  parsimonious model (see eq. 24) and the confidence bands (calculated as: Estimate  $\pm$  2  $\times$  Str.Error).

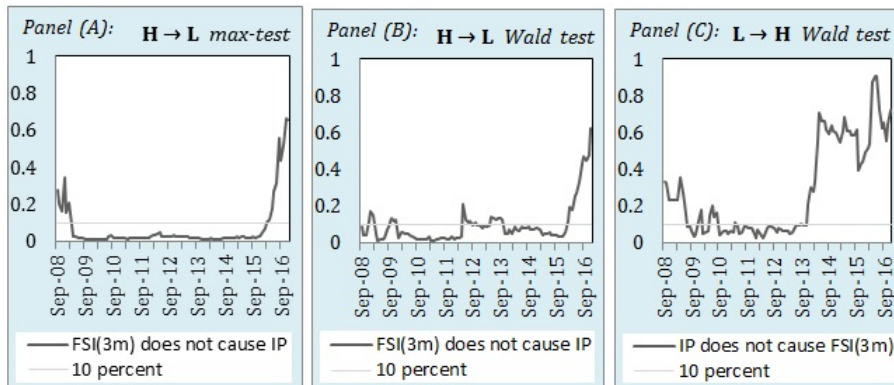
Fig. 11: *Daily* FSI (composed of 3 sub-indexes): the  $\beta_i$  coefficient values in each  $i^{th}$  model

Notes: The plot shows the point estimates of the coefficients  $\beta_i$  for each  $i^{th}$  parsimonious model (see eq. 24) and the confidence bands (calculated as: Estimate  $\pm$  2  $\times$  Str.Error). We consider a *daily* FSI constructed by aggregating only 3 sub-indexes: bond, equity and foreign exchange.

## A.4 Figures: rolling window analysis

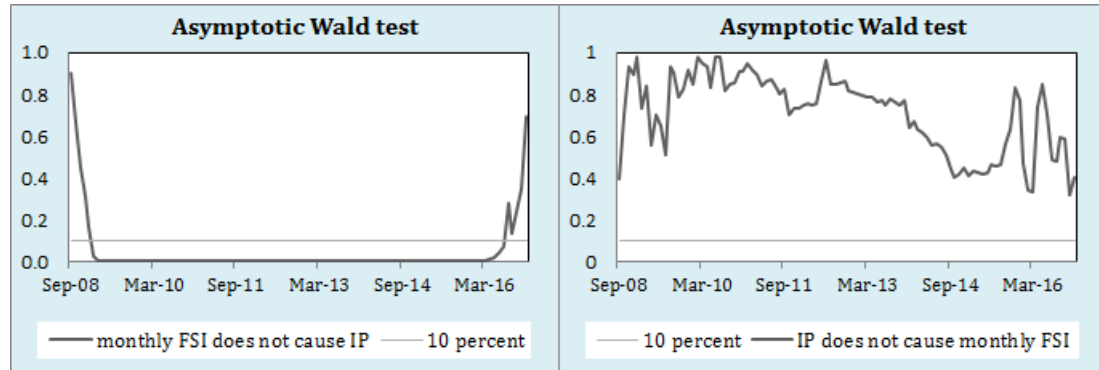
Fig. 12: P-values for rolling window analysis (*daily* FSI composed of 4 sub-indexes)

*Note:* We test for Granger causality between *daily* FSI for Lithuania (constructed in section 4) and *monthly* IP growth. Each test is based on MF-VAR (2) model and implemented by using a rolling window of 84 months (i.e. seven years). The x axes represent the 100 sub-samples, where the first sub-sample covers the period from October 2001 to September 2008, the second sub-sample covers the period from November 2001 to October 2008 and the last sub-sample covers January 2010 - December 2016 (the last observation of each sub-sample period is shown on the x axis). The y axes represent the p-values. The significance level of 10% is indicated by a light grey line.

Fig. 13: P-values for rolling window analysis (*daily* FSI composed of 3 sub-indexes)

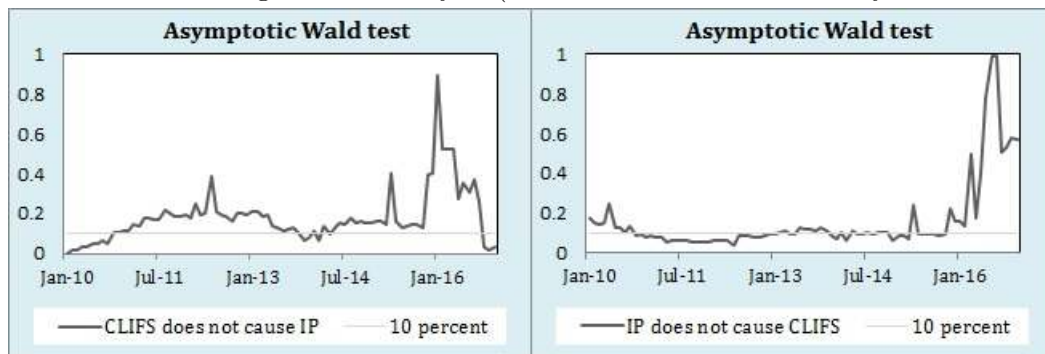
*Note:* We consider a *daily* FSI for Lithuania constructed by aggregating only 3 sub-indexes (bond, equity and foreign exchange). Each test is based on MF-VAR (2) model and implemented by using a rolling window of 84 months (i.e. seven years). The x axes represent the 100 subsamples, where the first covers the period from October 2001 to September 2008, the second one from November 2001 to October 2008 and the last one January 2010 - December 2016. The y axes represent the p-values. The significance level of 10% is indicated by a light grey line.

Fig. 14: P-values for rolling window analysis (*monthly* FSI composed of 4 sub-markets)



*Note:* We consider an asymptotic Wald test between common frequency variables: a *daily* FSI for Lithuania (composed of 4 sub-indexes) aggregated to *monthly* frequency and *monthly* IP growth. An optimal lag length for each sub-sample is obtained by using a SC criteria. Each test is implemented by using a rolling window of 84 months (i.e. seven years). The x axes represent the 100 subsamples, where the first covers the period from October 2001 to September 2008, the second one from November 2001 to October 2008 and the last one January 2010 - December 2016. The y axes represent the p-values. The significance level of 10% is indicated by a light grey line.

Fig. 15: P-values for rolling window analysis (CLIFS index for Lithuania by Kluas et al., 2017)



*Note:* We consider an asymptotic Wald test between monthly CLIFS index by ECB and monthly IP growth, implemented by using a rolling window of 84 months (i.e. seven years). An optimal lag length for each sub-sample is obtained by using a SC criteria. The x axes represent the 84 subsamples, where the first covers the period from February 2003 to January 2010, the second one from March 2003 to February 2010 and the last one January 2010 - December 2016. The y axes represent the p-values. The significance level of 10% is indicated by a light grey line.

## A.5 Tables

Table 1: Indicators used for the Lithuanian FSI construction

Market	Indicator	Notation
Bond market	Realized daily volatility of 10y Lithuanian government bond yields	$VrR10_t$
	Cumulative difference of Lithuanian and German 10y bond yields	$CDIFF_t$
Equity market	Realized daily volatility of OMXV	$VOMXV_t$
	The cumulative maximum loss (CMAX) of OMXV	$CMAX_t$
Foreign exchange market	Realized daily volatility of REER	$VREER_t$
	Cumulative change over six months of REER	$CUMUL_t$
Banking sector: Swedbank	Realized volatility of the idiosyncratic Swedbank stock price returns	$VBKS_{Swed,t}$
	CMAX of Swedbank stock prices	$CBKS_{Swed,t}$
Banking sector: SEB bank	Realized volatility of the idiosyncratic SEB bank stock price returns	$VBKS_{SEB,t}$
	CMAX of SEB bank stock prices	$CBKS_{SEB,t}$
Banking sector: DnB bank	Realized volatility of the idiosyncratic DnB stock price returns	$VBKS_{DnB,t}$
	CMAX of DnB bank stock prices	$CBKS_{DnB,t}$

Notes: all data is in real terms.

Table 2: Lithuanian's major trading partners, market share in %

	EZ	EE	LV	CN	CZ	DK	JP	NO	PL	RU	SE	TR	US	GB	Tot
$LT$	41.6	2.9	6.8	4.3	2.1	2.9	0.7	1.6	9.5	7.6	4.1	0.9	3.2	3.1	91.4
$LT_{adj}$	45.5	3.2	7.5	4.7	2.3	3.1	0.8	1.8	10.4	8.4	4.5	1.0	3.5	3.4	100

Notes: based on trade in 2008 – 2010. EZ – Eurozone (Austria 1.4, Belgium 4.0, Finland 2.7, France 4.8, Denmark 17.1, Ireland 0.3, Italy 5.3, Luxembourg 0.2, Netherlands 3.8, Portugal 0.3, Spain 1.7); EE – Estonia, LV – Latvia CN – China, CZ – Czech Republic, DK – Denmark, JP – Japan, NO – Norway, PL- Poland, RU-Russia, SE- Sweden, TR – Turkey, US- United States, GB- United Kingdom. Data is taken from BIS.

Table 3: P-values for Granger Causality test (full sample analysis)

Panel (A): <b>Daily FSI (including 4 sub-indexes) and monthly IP growth</b>			
H <sub>0</sub> : <i>daily</i> FSI $\rightarrow$ <i>monthly</i> IP growth		H <sub>0</sub> : <i>monthly</i> IP growth $\rightarrow$ <i>daily</i> FSI	
Test	Wald test (bootstrap version)	max-test	Wald test (bootstrap version)
<b>MF-VAR(1)</b>	0.001	0.004	0.233
<b>MF-VAR(2)</b>	0.026	0.008	0.127
<b>MF-VAR(3)</b>	0.071	0.013	0.394

Panel (B): <b>Daily FSI (3 sub-indexes) and monthly IP growth</b>			
H <sub>0</sub> : <i>daily</i> FSI $\rightarrow$ <i>monthly</i> IP growth		H <sub>0</sub> : <i>monthly</i> IP growth $\rightarrow$ <i>daily</i> FSI	
Test	Wald test (bootstrap version)	max-test	Wald test (bootstrap version)
<b>MF-VAR(1)</b>	0.001	0.006	0.236
<b>MF-VAR(2)</b>	0.009	0.014	0.314
<b>MF-VAR(3)</b>	0.080	0.019	0.472

Panel (C): <b>Monthly FSI (4 sub-indexes) and IP growth</b>			
H <sub>0</sub> : <i>monthly</i> FSI $\rightarrow$ <i>monthly</i> IP		H <sub>0</sub> : <i>monthly</i> IP $\rightarrow$ <i>monthly</i> FSI	
	Wald test (bootstrap version)	Wald test (asymptotic)	Wald test (asymptotic)
CF-VAR(1)	0.001	0.000	0.850

Panel (D): <b>Monthly ECB Country-Level FSI (3 sub-indexes) and IP growth</b>			
H <sub>0</sub> : <i>monthly</i> FSI $\rightarrow$ <i>monthly</i> IP		H <sub>0</sub> : <i>monthly</i> IP $\rightarrow$ <i>monthly</i> FSI	
	Wald test (bootstrap version)	Wald test (asymptotic)	Wald test (asymptotic)
CF-VAR(2)	0.209	0.181	0.140

*Notes:* In panel (A) and (B) we investigate the causality between daily and monthly series. For this, we fit a MF-VAR specification with 1, 2, 3 lags and we use a max-test by Ghysels et al. (2018) and bootstrap version of Wald test by Götz et al. (2016). In panel (C) and (D) we test for Granger causality between two monthly series. For this purpose, we fit a common-frequency VAR model, where the optimal lag length is chosen by using a Bayesian information criteria and we use an asymptotic and a bootstrap version of a Wald test.

Table 4: Regression results (full sample analysis)

Panel (A):		Panel (B):
<i>monthly</i> FSI (4 markets)		<i>monthly</i> CLIFS (by Duprey et al. (2017))
const	0.043 (0.008)***	0.018 (0.008)*
$IP_{t-1}$	0.520 (0.059)***	0.593 (0.079)***
$FSI_{t-1}$	-0.236 (0.049)***	-0.113 (0.086)
$IP_{t-2}$		0.115 (0.075)
$FSI_{t-2}$		0.039 (0.085)
Signif. codes:		0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05

Notes: panel (A) present the point estimates for the coefficients in  $IP_t = const_t + a \times IP_{t-1} + b \times FSI_{t-1} + u_t$  and panel (B) for the coefficients in  $IP_t = const_t + \sum_{k=1}^2 a_k \times IP_{t-k} + \sum_{k=1}^2 b_k \times CLIFS_{t-k} + u_t$ .

Table 5:  $Q$  test (full sample analysis)

	Lag order (p, pm):	k = 1	k = 5	k = 18
<b>FSI with 4 sub-sectors</b>	MF-VAR (1)	0.624	0.887	0.035
	MF-VAR (2)	0.987	0.981	0.119
	MF-VAR (3)	0.796	0.68	0.023

Notes: We find that a model with  $p=2$  and  $pm=36$  is better specified in terms of absence of residual correlation than other models taken under the consideration. In fact, when the model is fitted with  $p=2$  and  $pm=36$  we cannot reject the null hypothesis of no serial correlation in the residuals at 5% significance level, since the p-values of the test are  $\{0.987, 0.981, 0.119\}$ , respectively, for each lag  $\{1, 5, 18\}$ .







## Projection Clustering Unfolding: a new algorithm for clustering individuals or items in a preference matrix

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**Abstract** In the framework of preference rankings, the interest can lie in clustering individuals or items in order to reduce the complexity of the preference space for an easier interpretation of collected data. The last years have seen a remarkable flowering of works about the use of decision tree for clustering preference vectors. As a matter of fact, decision trees are useful and intuitive, but they are very unstable: small perturbations bring big changes. This is the reason why it could be necessary to use more stable procedures in order to clustering ranking data. In this work, a Projection Clustering Unfolding (PCU) algorithm for preference data will be proposed in order to extract useful information in a low-dimensional subspace by starting from an high but mostly empty dimensional space. Comparison between unfolding configurations and PCU solutions will be carried out through Procrustes analysis.

**Keywords** Projektion pursuit · Preference data · Clustering rankings

**Riassunto** *Nell'ambito delle classifiche di preferenza, uno degli obiettivi potrebbe consistere nel raggruppare gli individui o gli oggetti al fine di ridurre la complessità dello spazio di preferenza, per un'interpretazione più semplice dei dati raccolti. Gli ultimi anni hanno visto una notevole fioritura di articoli sull'uso degli alberi decisionali per il raggruppamento dei vettori*

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di preferenze. Tuttavia va detto che, se da un lato gli alberi decisionali sono utili e intuitivi, dall'altro sono molto instabili: piccole perturbazioni possono condurre a grandi cambiamenti. Questo è il motivo per cui potrebbe essere necessario utilizzare procedure più stabili al fine di raggruppare i dati di ranking. In questo lavoro, verrà proposto un algoritmo di *Projection Clustering Unfolding (PCU)* per i dati delle preferenze per estrarre informazioni utili in un sottospazio a bassa dimensione partendo da uno spazio dimensionale alto ma per lo più vuoto. Il confronto tra le configurazioni di proiezione e le soluzioni PCU sarà effettuato attraverso l'analisi procustiana.

**Parole chiave** Tecniche di proiezione - Dati di preferenza - Tecniche di raggruppamento per graduatorie

## 1 Introduction

Projection pursuit includes a lot of techniques for finding interesting projections of multivariate data in low dimensional spaces (Friedman and Tukey, 1974). One particular structure is that of clusters in the data. Projection Pursuit Clustering (PPC) is a synthesis of projection pursuit and nonhierarchical clustering methods that simultaneously attempts to cluster the data and to find a low-dimensional representation of this cluster structure. As introduced by Huber (1985), a Projection Pursuit (PP) algorithm consists of two components: an index function  $I(\alpha)$  that measures the “usefulness” of projection and a search algorithm that varies the projection direction so as to find the optimal projections, given the index function  $I(\alpha)$  and the data set  $X$ . In this work we propose an iterative strategy that combine suitable clustering methods for preference rankings with Multidimensional unfolding techniques. We call our proposal *Projection Clustering Unfolding*. All the methodology is illustrated and evaluated on one real and well known dataset.

## 2 Preference data

In every day life ranking and classification are basic cognitive skills that people use in order to graduate everything that they experience. Grouping and ordering a set of elements is considered easy and communicative, so often it happens to observe rankings of sport-teams, universities, countries and so on. A particular case of ranking data is represented by preference data, in which individuals show their preferences over a set of alternatives, items from now on. Since preference rankings can be considered as indicators of individual behaviours, when subject-specific characteristics are available, an important issue relies on the identification of profiles of respondents giving same/similar rankings.

Ranking data arise when a group of judges is asked to rank a fixed set of objects (*items*) according to their preferences. When ranking  $k$  items, labeled  $1, \dots, k$ , a ranking  $\pi$  is a mapping function from the set of items  $\{1, \dots, k\}$  to the set of ranks  $\{1, \dots, k\}$ , endowed with the

natural ordering of integers, where  $\pi(i)$  is the rank given by the judge to item  $i$ <sup>1</sup>. When all  $k$  items are ranked in  $k$  distinct ranks, we observe a complete ranking or *linear ordering* (Cook et al., 1986). Yet, it is also possible that a judge fails to distinguish between two or more objects and assigns them equally, thus resulting in a tied ranking or *weak ordering*. Besides complete and tied rankings, *partial* and *incomplete rankings* exist: the first occurs when only a specific subset of  $q < k$  objects are ranked by judges, while incomplete ranking occurs when judges are free to rank different subsets of  $k$  objects (Cook et al., 1986). Obviously, different types of ordering will generate different sample space of ranking data. With  $k$  objects there are  $k!$  possible complete rankings; this number gets even larger when ties are allowed (for the cardinality of the universe when ties are allowed refer to Good (1980) and Marcus (2013)). From a methodological point of view, preference analysis often models the probability for certain preference structures, finally providing the probabilities for choosing one single object. Many models have been proposed over the years, such as order statistics models, distance-based models and Bradley-Terry models. Moreover, in order to incorporate subject specific covariates, extension of the above mentioned models have been proposed, such as distance based tree models (Lee and Philip, 2010), decision tree models with ad-hoc impurity functions (Yu et al., 2011; Plaia and Sciandra, 2017), distance-based multivariate trees for rankings (D’Ambrosio and Heiser, 2016) and some log-linear version of standard Bradley-Terry models (Dittrich et al., 1998). Recently, model-based clustering algorithms to analyse and explore ranking data have been proposed in literature (Jacques and Biernacki, 2014; Biernacki and Jacques, 2013). Yet, it is important to note that the classical cluster algorithm not always can be extended to preference data, because the concept of clustering for this type of data is not unique: in presence of preference data, clustering can be done over the individuals or over the objects. Often rank data can reveal simultaneous clusters of both individuals and items.

### 3 Projection pursuit

Projection pursuit includes a lot of techniques for finding interesting projections of multivariate data in low dimensional projections (Friedman and Tukey, 1974). One particular structure is that of clusters in the data. Projection Pursuit Clustering (PPC) is a synthesis of projection pursuit and nonhierarchical clustering methods that simultaneously attempts to cluster the data and to find a low-dimensional representation of this cluster structure.

One of the most important features of PP is that it is one of the few multivariate methods able to bypass the “curse of dimensionality” problem. Many of the methods of classical multivariate analysis turn out to be special cases of PP, for example principal components and discriminant analysis.

How does PP work? When PP is performed on a small number of dimension, it is possible to examine essentially all such projections to select those of interest: the appearance of the

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<sup>1</sup> Preference rankings can be represented through either rank vectors (as in this paper) or order vectors D’Ambrosio et al. (2015).

projected data set does not change abruptly as the projection direction changes, and the space of projection directions will be of low dimensionality. When the projection is made up in higher dimensions, the appearance of the projected data will still smoothly change, but it becomes increasingly impractical to explore possible projections exhaustively (Tukey and Tukey, 1981). Projection pursuit works by associating a function value to each and every low-dimensional projection. This function value must be a measure of "interestingness" so it should be large for projections revealing interesting structure, and small for uninteresting ones. Then, PP could be defined as the process of making such selections by the local optimisation over projection directions of some index of "interestingness". The notion of "interesting projection" has usually been defined referring to departure from normality (Huber, 1985), but several alternatives have been proposed also looking for multimodality (Nason and Sibson, 1992) or clustering. Once an objective function  $I$ , called *projection index* and depending on a normalized projection vector  $\alpha$ , is assigned to every projection characterizing the structure present in the projection, interesting projection are then automatically picked up through a numerical optimization of the projection index. One of the most common problems in PP is the oscillating behaviour of the projection indices: often procedures looking for the most interesting projection stop at the nearest local optimum from the starting point. So several authors devoted their works to avoid the local property of the optimization algorithm (Hall, 1988; Posse, 1995). A way for catching all and only all significantly interesting projections is to extract them in a monotonic way from the most structured projection to the less but still useful solution. In its classical notation a PP can be summarized as follows. Let  $X$  be either a  $P$ -dimensional random vector (distributional) or some  $P \times N$  data matrix (sample). To form a univariate linear projection of  $X$  onto the real line we require a  $P$ -vector  $a$ . This vector might as well be of unit length, since it is only the direction of projection that is of interest. The projected data,  $Z$ , are formed by  $Z = a^\top X$ . For a linear projection onto  $K$  ( $K < P$ ) dimensions we require a  $P \times K$  matrix  $A$ , and the projected data,  $Z$ , are formed by  $Z = A^\top X$ . If the columns of  $A$  form an orthonormal set then the projection will be orthogonal.

The measure of "interestingness" evaluated by the projection index  $I$ , then will be expressed as

$$I(Z) = I(A^\top X) = I(A).$$

These interesting projections will be evidence of structure within the multivariate set and may form the basis of hypotheses which may be confirmed by more traditional statistical methods.

### 3.1 Projection Indexes

The aim of projection pursuit is to reveal possible non-linear and therefore interesting structures hidden in the high-dimensional data. As introduced before, to what extent these structures are "interesting" is measured by an index. Principal components analysis, for example, can be seen as a projection pursuit method in which the index of "interestingness"  $I(a)$  is in this case the proportion of the total variance accounted for by a linear combination  $a^\top X$  subject to the

normalizing constraint  $a^\top a = 1$ . In this particular case, this projection index is simple to maximize and has an algebraic solution; however this is the exception rather than the rule. Most projection indexes require an algorithm that will calculate  $I$  at values of  $a$  and maximize  $I$  according to some numerical optimization routine.

Several projection indexes have been proposed in literature. Since the work of Huber (1985), and more recently Hall and Li (1993), the notion of an “interesting projection” has been clearly defined as one exhibiting departure from normality. Consequently, test for non-normality were thought as suitable projection indexes. But it has also been shown that in order a projection index to be considered efficient, must satisfy basic requirements, namely affine invariance (Huber, 1985), consistency (Hall, 1988), simplicity and sensitivity to departure from normality in the core rather than in the tails of the distribution. Friedman and Tukey (1974) developed a hill-climbing optimisation methods to find interesting projections. The index they used for 1-dimensional projection pursuit can be written as a combination of two components  $I(a) = s(a)d(a)$ , where  $s(a)$  measures the general spread of the data, and  $d(a)$  measures the local density of the data after projection onto a projection vector  $a$ . In defining a projection index, Friedman and Tukey (1974) thought was interesting within a projection and tried to optimise a projection index to maximise this; as an alternative, Jones and Sibson (1987) defined a measure of un-interesting projections and attempted to maximise divergence away from it. Other projection indexes were based on some measure of entropy (Yenyukov, 1989); Jones and Sibson (1987) developed an approximation to the entropy index, called the moment index, which is based on summary statistics of the data (more precisely the third and fourth outer product tensors). Very few projection pursuit indices incorporate class or group information in the calculation. Hence, they cannot be adequately applied in *supervised* classification problems to provide low dimensional projections revealing class differences in the data. Aim of the projection Pursuit Clustering (PPC) is to recover clusters in lower dimensional subspaces of the data by simultaneously performing dimension reduction and clustering. Therefore, results from a PPC algorithm could make possible to use them as a first step of *unsupervised* classification problems.

#### 4 Projection pursuit clustering

Bolton and Krzanowski (2003) define Projection Pursuit Clustering as the synthesis of a projection pursuit algorithm and nonhierarchical clustering methods that simultaneously attempts to cluster the data and to find a low-dimensional representation of this cluster structure. Aim of the PPC is to seek, in high dimensional data, a few interesting low-dimensional projection that reveal differences between classes. PPC works as follows: iteratively it finds both an optimal clustering for a subspace of given dimension and an optimal subspace for this clustering. Some authors have already associated PP with clustering; for example Eslava and Marriott (1994) proposed the use in a PP algorithm of projection indexes with class information able to uncover low-dimensional cluster structure; Lee et al. (2005) proposed the LDA (linear dis-

criminant analysis) projection pursuit index using class information through an extension of the linear discriminant analysis idea. Lee and Cook (2010) developed a Penalized Discriminant Analysis (PDA) index useful when data exhibit high correlation data or for situations with a small number of observations over a large number of variables.

Other contributions looked at MDS (multidimensional scaling) in terms of projection pursuit by identifying the *stress* function with the projection index and constrain the multidimensional configuration to orthogonal projections of the data Borg and Groenen (1997). In a more recent work Lee and Philip (2010) developed a projection pursuit classification tree, a new approach to build a classification tree using projection pursuit indices with class information. A PP step is performed at each node so that the best projection is used to separate two groups of classes using various projection pursuit indices with class information. One class is assigned to only one final node and the depth of the projection pursuit classification tree cannot be greater than the number of classes. The projection coefficients of each node can be interpreted as the importance of the variables to the class separation of each node; then the way in which these coefficients change should be useful to explore how classes are separated in a tree.

## 5 Clustering preference data

In dealing with preference rankings, one of the main issues is to identify homogeneous sub-populations of judges when heterogeneity among them is assumed. This is exactly the goal of clustering methods. Projection pursuit-based clustering methods have been proposed over the year in order to deal with a large variety of data (Friedman and Tukey, 1974; Bock, 1987; Heiser and Groenen, 1997; Miasnikov et al., 2004). As a matter of fact, there are no proposals that allow to deal with preference data. Preference rankings are characterized by a set of items, or objects, and a set of judges, or individuals, that have to rank the items according to their preference. Clustering methods for preference rankings can be done over the individuals (Murphy and Martin, 2003; Jacques and Biernacki, 2014), or over the objects (Marden, 2014). Often rank data can reveal simultaneous clusters of both individuals and items. Multidimensional unfolding techniques can graphically show such a situation (De Soete and Heiser, 1993). Here we combine suitable clustering methods for preference rankings with Multidimensional unfolding techniques. Our approach is similar to the Cluster Differences Unfolding (CDU) (Vera et al., 2013), which can be considered as the natural extension to Unfolding of the Cluster Difference Scaling (CDS) (Heiser, 1993). The main difference is that CDU, which is devoted to metric Unfolding, performs a cluster analysis over both the sets of individuals and objects, producing a configuration plot that shows the bari-centers of the sets retaining their preference relationship.

Here we propose an iterative strategy that performs a non-hierarchical cluster analysis on only one set, typically the individuals, leaving the other set free to be configured in the reduced geometrical space in such a way that the relationships between the preference order of the individuals with respect to the items remain unchanged. We call our proposal *Projection Clustering Unfolding* (PCU).

### 5.1 The *Projection Clustering Unfolding* (PCU)

Unfolding can be seen as a particular Multidimensional Scaling technique for rectangular data, in general showing preference of  $n$  persons for  $m$  objects. The most accepted formulation of the problem in terms of a badness-of-fit function is given in a least squares framework by the minimization of the *stress* function (Kruskal, 1964), defined as

$$\sigma^2(\mathbf{A}, \mathbf{B}, \hat{\mathbf{\Delta}}) = \sum_{i=1}^n \sum_{j=1}^m (\hat{\delta}_{ij} - d_{ij})^2, \quad (1)$$

where  $\hat{\mathbf{\Delta}}$  is a  $n \times m$  matrix in which each entry  $\hat{\delta}_{ij}$  represents the disparity or monotonically transformed dissimilarity between the  $i$ th individual and the  $j$ th item, and  $d_{ij} = d_{ij}(\mathbf{A}, \mathbf{B})$  represents the Euclidean distance between the individuals' ( $\mathbf{A}$ ) and items ( $\mathbf{B}$ ) configuration points in  $P$ -dimensional space,  $i = 1, \dots, n$ ,  $j = 1, \dots, m$  (Borg and Groenen, 1997).

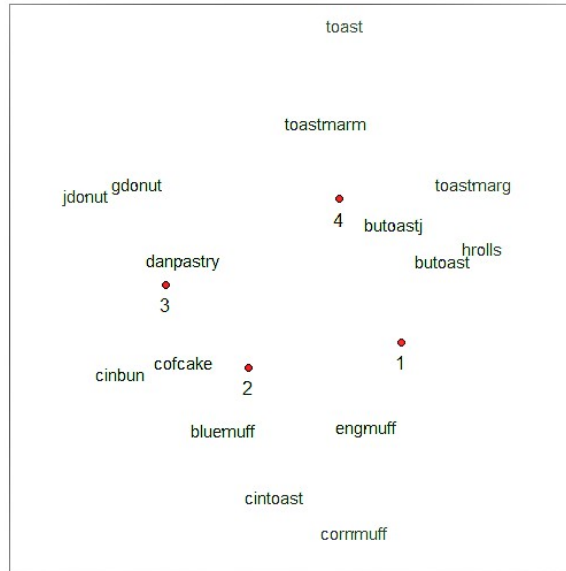
Here we assume that  $\mathbf{A} = \mathbf{GX}$ , where  $\mathbf{G}$  is a  $n \times K$  indicator matrix whose elements  $g_{ik}$ ,  $k = 1, \dots, K$ , are equal to one if the  $i$ th individual belongs to the  $k$ th cluster, and zero otherwise. We assume that  $g_{ik} \cap g_{il} = \emptyset$  for  $k \neq l = 1, \dots, K \forall i = 1, \dots, n$ .  $\mathbf{X}$  is the  $K \times P$  matrix of the bari-centers of the  $K$  clusters, where  $P$  indicates the dimension of the Unfolding solution. We propose an alternating optimization strategy that, given a configuration of both the individuals and the items, searches the optimum partition of the individuals in  $K$  clusters. Then, given the optimal partition of the individuals, the configuration of both individuals and items are updated. The first step consists in a first unfolding configuration with a random assignment of the individuals to the  $K$  clusters. As Unfolding model, we use the PREFSCAL algorithm (Busing et al., 2005), which is particularly feasible when dealing with ordinal Unfolding, that penalizes the stress function and uses the SMACOF-3 algorithm (Heiser, 1981) as optimization engine.

### 5.2 The *Projection Clustering Unfolding*: a real example

As an example, we analyse the well-known breakfast data set (Green and Rao, 1972). Breakfast data contains the preferences of 42 individuals towards 15 breakfast items from the most preferred (1) to the least preferred (15). We set  $K = 4$  clusters and the simplest approach to the ties, i.e. untie tied observations. As the final solution is sensitive to the random choice of the clusters at the first step, we repeated the analysis 20 times, obtaining the configuration shown in Figure 1.

The figure shows the configuration of the 4 cluster centers in the 2-dimensional solution. We expect that the closer the bari-centers are to the items, the higher is the preference of that cluster to that items. We ran the Unfolding analysis without any restrictions on the same data, and then we performed a Procrustes analysis (Borg and Lingoes, 1987) by considering the unrestricted solution as target configuration. Procrustes analysis allows to evaluate the ability to reproduce the configuration both graphically and with the  $L$ -statistic, which is the





**Fig. 1** Projection Clustering Unfolding solution. Items are coded as: toast=toast pop-up; butoast=buttered toast; engmuff=English muffin and margarine; jdonut=jelly donut; cintoast=cinnamon toast; bluemuff=blueberry muffin and margarine; hrolls=hard rolls and butter; toastmarm=toast and marmalade; butoastj=buttered toast and jelly; toastmarg=toast and margarine; cinbun=cinnamon bun; danpastry=Danish pastry; gdonut=glazed donut; cofcake=coffee cake; cornmuff=corn muffin and butter.

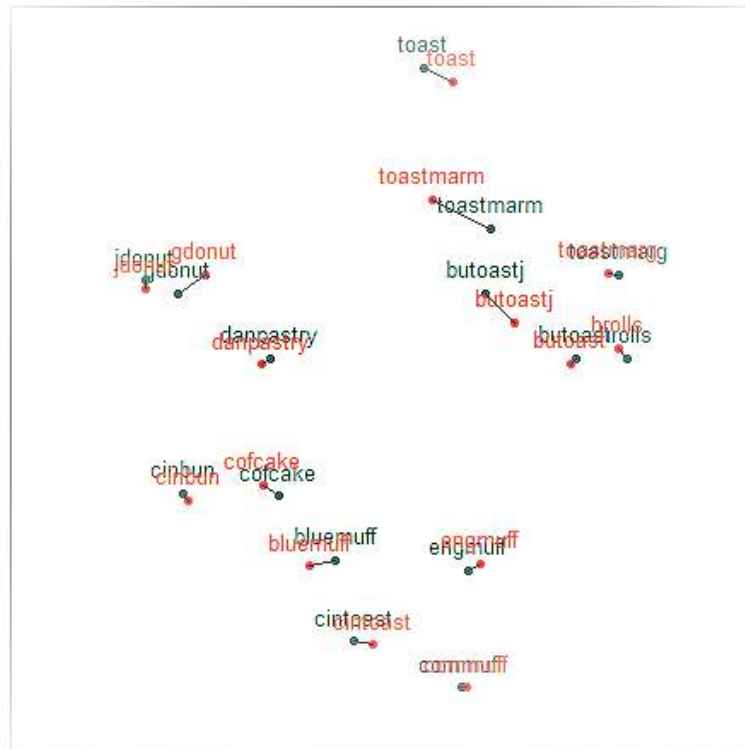
sum of the squared differences between the true and the fitted configuration after that both configurations are set into optimal correspondence through Procrustean transformation. The lower the Procrustes statistic, the better the fitted configuration. We used a normalized version of the Procrustes statistic as suggested by Deun et al. (2007):

$$L(\mathbf{X}, \hat{\mathbf{X}}) = \frac{\text{tr}((\mathbf{X} - \hat{\mathbf{X}})^T(\mathbf{X} - \hat{\mathbf{X}}))}{\text{tr}(\mathbf{X}^T \mathbf{X})}, \tag{2}$$

where  $\mathbf{X}$  is the true configuration and  $\hat{\mathbf{X}}$  is the fitted one.

Figure 2 shows the Procrustes configuration plot limited to only the objects points. The recovery is excellent, also confirmed by a value of  $L = 0.013$ .

Figure 3 shows the Procrustes plot for the individuals' point configurations ( $L = 0.161$ ). This figure gives an idea of the composition of the clusters in terms of the allocation of the individuals around the cluster centers.



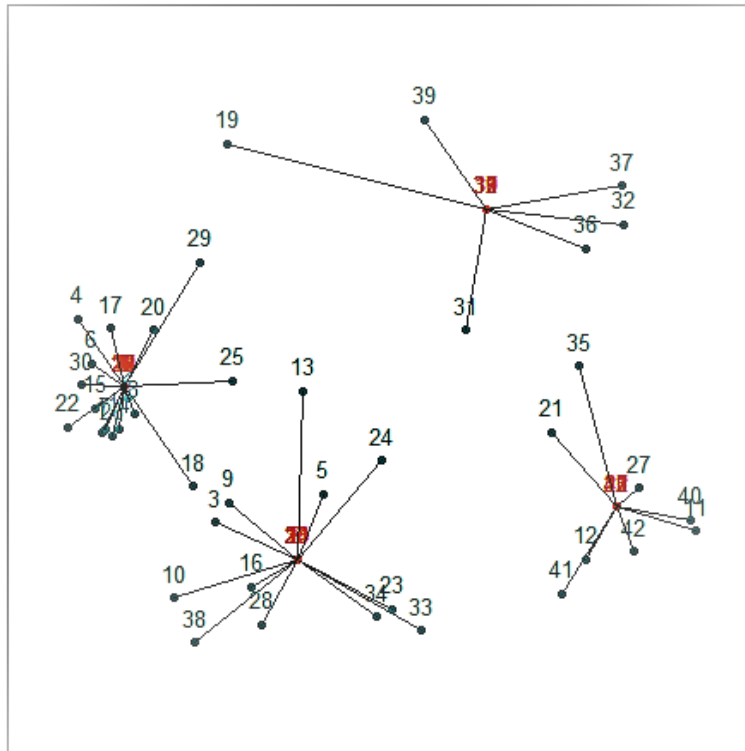
**Fig. 2** Procrustes configuration plot: objects' points unfolding configuration (green) vs objects' points PCU solution (red).

Figure 4 shows the overall Procrustes configuration plot ( $L = 0.091$ ). This graphical representation shows that the PCU solution (red) is really similar to the unrestricted Unfolding analysis (red) in terms of interpretation.

Both the graphical representation and the  $L$ -statistic confirm that the PCU procedure does not distort the original Unfolding analysis. Of course, the technical settings have been set equal for both Unfolding and PCU.

After the Procrustes analysis we performed a last allocation step. We first computed the squared Euclidean distance between the unrestricted unfolding solution and the (fitted and scaled) PCU configuration, and then we assigned the individuals to the clusters with a procedure similar to the one of the K-means. We obtained the following confusion matrix:

		Unfolding Alignment			
		Cluster 1	Cluster 2	Cluster 3	Cluster 4
PCU	Cluster 1	8	0	0	0
	Cluster 2	0	12	0	0
	Cluster 3	0	0	16	0
	Cluster 4	0	0	1	5



**Fig. 3** Procrustes configuration plot: individuals' points unfolding configuration (green) vs individuals' points PCU solution (red).

This matrix shows that there is only one individual that is wrongly ‘classified’ in the unrestricted Unfolding solution with respect to the PCU, that has been identified as the individual number 19.

In order to check the homogeneity of the analysis in terms of preference rankings, we computed the median ranking within each cluster. We obtained the results shown in Table 1. These median rankings can be interpreted as the bari-centers in terms of preference rankings. We noticed that the results are consistent with the graphical solution. Last row shows the averaged  $\tau_X$  rank correlation coefficient (Emond and Mason, 2002) within cluster, which informs about the goodness of the solution of the median ranking problem. The last column shows the median ranking of the entire data set. It can be noticed that the homogeneity in terms of  $\tau_X$  rank correlation coefficient is much larger within each cluster.

As a global homogeneity measure of the PCU, we can compute the quantity  $H = \sum_{k=1}^K \tau_{X_k} \pi_k$ , where  $\pi_k$  is the proportion of cases in the  $k$ th cluster. The shown configuration returns  $H = 0.575$ , which is about 1.877 times larger than the homogeneity of the entire data set.



**Table 1** Median ranking within cluster

Item	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Median ranking Breakfast data
toast	13	13	15	7	15
butoast	1	10	11	1	11
engmuff	2	3	7	8	6
jdonut	15	12	3	6	7
cintoast	5	5	8	13	8
bluemuff	6	2	6	9	3
hrolls	4	9	14	2	12
toastmarm	8	8	10	2	10
butoastj	7	7	9	2	9
toastmarg	3	11	12	3	13
cinbun	12	4	5	10	4
danpastry	10	4	1	4	1
gdonut	14	6	4	5	5
cofcake	9	1	2	11	2
cornmuff	11	6	13	12	14
$\tau_X$	0.554	0.520	0.647	0.514	0.306

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