Irving Fisher Committee on
Central Bank Statistics

BANK FOR INTERNATIONAL SETTLEMENTS

IFC – Bank Indonesia International Workshop and Seminar on *"Big Data for Central Bank Policies / Building Pathways for Policy Making with Big Data"*

Bali, Indonesia, 23-26 July 2018

# Big data for central banks[1]

Bruno Tissot,

Bank for International Settlements

[1] This presentation was prepared for the meeting. The views expressed are those of the author and do not necessarily reflect the views of the BIS, the IFC or the central banks and other institutions represented at the meeting.

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# Big Data for Central Banks

Bruno TISSOT
Head of Statistics and Research Support, BIS
Head of Secretariat, Irving Fisher Committee on Central Bank Statistics (IFC)

*International Workshop on Big Data for Central Bank Policies – Bali, 23-25 July 2018*
*Session 1*

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# Overview

- Introduction
- Financial Big Data
- Three key developments
- Challenges in handling and using big data
- Analysing CBs' experiences
- Annexes: Selected references/ BD projects by CBs

# Introduction – Big Data…

- General & increasing **policy interest** for "Big Data" (BD)

→ *the world's most valuable resource is no longer oil, but data* (The Economist)

- Term **usually describes**
  - Extremely large data-sets
  - Often a by-product of commercial or social activities
  - Huge amount of granular information, typically transaction-level
  - Data available in, or close to, real time
  - Used to identify behavioural patterns / economic trends

→ ***Growing impact*** *on information creation, storage, retrieval, methodology, analysis*



# Introduction – … for Central Banks…

- **Private sector** use big data to produce new & timely indicators

- New opportunities **also for Central Banks (CBs)** – as well as macro-prudential authorities and financial supervisors?
  - Broader and timelier range of indicators
  - New statistical methodologies

- Extraction of **new type of information** supporting
  - Economic forecasts & analysis
  - Financial stability work
  - Policy impact evaluation

# Introduction – … with significant opportunities…

- **Focus on sources** that can effectively support micro- and macro-economic as well as monetary and financial stability analyses
  - Other big data – eg geospatial information – of lower interest
- **Feedback loop** inherent to policy-making authorities
  - Big data sources can affect policy-making
  - In turn policies implemented can generate new data-sets
- Big data provide **new "business opportunities"** for CBs, such as:
  - Qualitative statements to decipher central banks' communication
  - Large number of big data pools generated by financial regulations
  - In turn, big data can strengthen supervisors' capacity



# Introduction – … but also challenges…

- Specific **challenges faced in handling and using** big data
  - Public nature of financial authorities and public trust
  - Central banks concerned about ethical & reputational consequences
  - Risk of misusing big data for policy actions?

- Different **data quality concerns** compared to private sector
  - Ex: online retailers targeting potential customers based on past web searches might find it acceptable to be "right" 20% of the time
  - Such a low  accuracy level looks inadequate for official statisticians



# Introduction – … not least due to security concerns…

- Increasing **security concerns linked** to internet / big data, such as:
  - Risk that large private records of individual information could be accessed and potentially misused by unauthorized third-parties
  - Resilience of financial market infrastructures

- **Influence on central banks'** actions
  - Preserve public trust, especially when collecting data
  - Supervise firms' capability to gather and interpret security-related information
  - Set standards and best practices
  - Promote cyber threat intelligence and modelling techniques



# Introduction – … with the risk of being behind…

- **CBs' constraints** compared to private firms
  - Basic resources needs (IT budget, staff)
  - Concerns about the lack of transparency in methodologies
  - Poor quality of some data sources hampering public use
- **IFC survey** of central banks
  - Big data work still on an exploratory mode
  - Regular production of big data-based information likely to take time
  - Yet increased interest esp. at senior policy level



# Introduction – … and the need to be proactive

- Key objective for central banks is to **better understand**
  - The new data-sets and related methodologies for their analysis
  - The value added in comparison with "traditional" statistics
- Focus on **pilot projects** to assess how big data can help to
  - Better monitor the economic and financial situation
  - Enhance the effectiveness of policy
  - Assess the impact of policy actions
- Possible tasks may well **further expand**
  - Constant creation of new information/research needs
  - Cf Haldane (2018): exploring behaviours in a "virtual economy"



# I – What is Financial Big Data?

- **Broad approach for BD**: by-product of commercial or social activities, providing a huge amount of very granular information

- **Yet**:
  - Not sufficient to be large to qualify as "big data" – cf census
  - Unstructured data require new tools to be processed
  - Structured data-sets handled with "traditional" techniques?

- Choice of the **relevant metric**
  - Volume of data?
  - Specific characteristics of big data-sets?
  - Timing issue? "Big data" 10 years ago versus today



# I –Financial Big Data: 3 main BD groups…

- Definition by United Nations Department of Economic and Social Affairs

- Big data type of information **classified in three groups,** as a product of:
  1. **Social networks** (human-sourced information, eg blogs, videos, searches)
  2. **Traditional business systems** (process-mediated data, such as data produced by commercial transactions, e-commerce, credit cards)
  3. **The internet of things** (machine-generated data, such as data produced by pollution/traffic sensors, mobile phone information, computer logs)



# I – Financial Big Data: … with a key distinction…

- 1. **Unstructured data-set** (often quite large):
  - By-product of a non-statistical activity – "produced **organically**"
  - Different from the datasets produced for traditional statistics, which are structured by **design**

- 2. **Data-set with large records, relatively** well-structured
  - **Difficult** to handle because of size, granularity or complexity
  - Even "simple" structured datasets can **benefit from big data techniques**

# I – Financial Big Data: … some judgment…

- Room for **judgment**, depends on **features such as the "Vs"**
  - **Volume** (number of records and attributes)
  - **Velocity** (speed of data production, eg tick data)
  - **Variety** (for instance structure and format)
  - **Veracity** (accuracy / uncertainty of large individual records)
  - **Valence** (interconnectedness of the data)
  - **Value** (often a by-product of an activity, can trigger a monetary reward)
- Features characterising big data can be very **diverse**
- **Information content** also quite heterogeneous



# I – Financial Big Data: … 2 main sources for CBs…

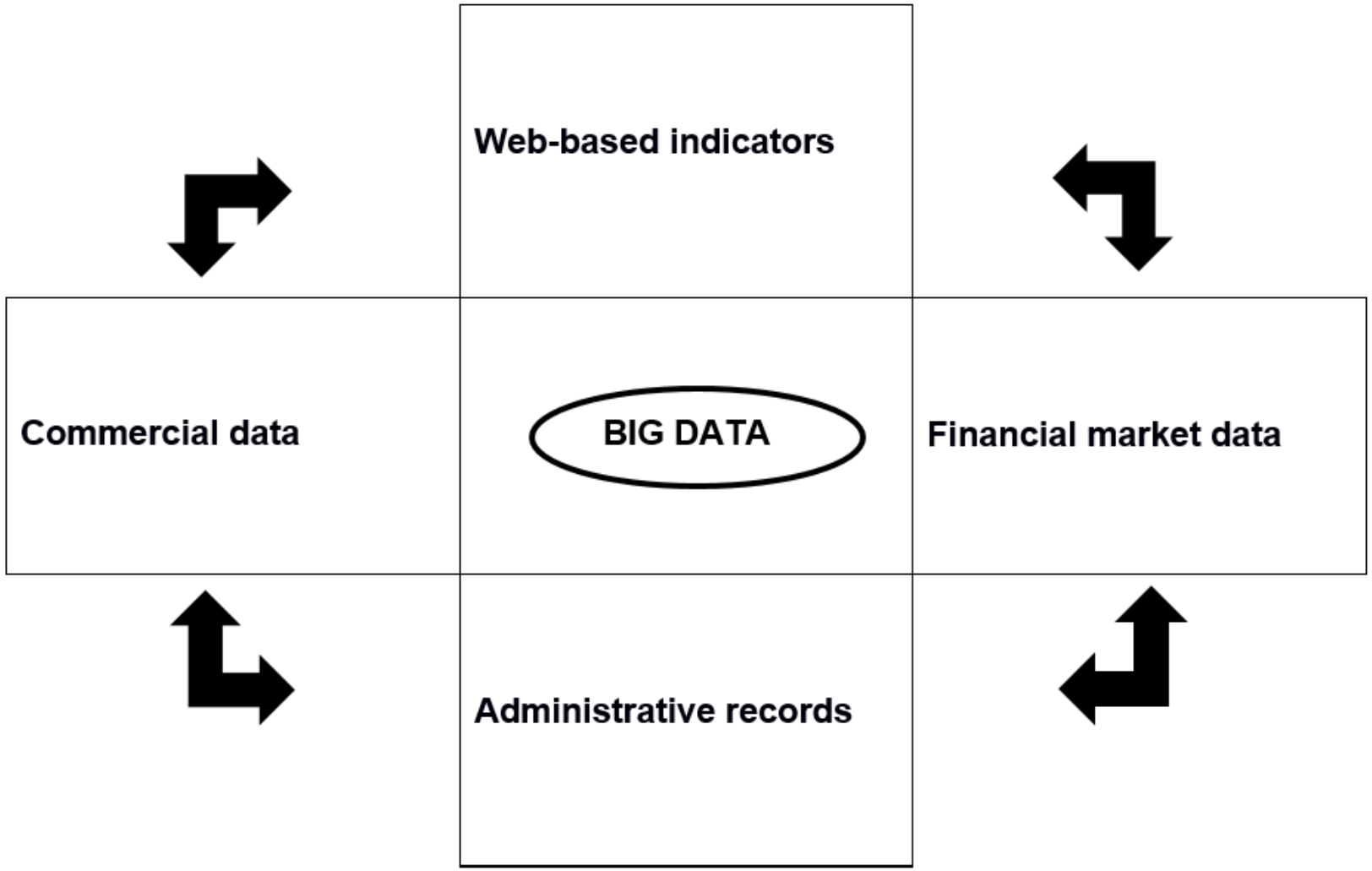
- CBs see Big Data as comprising the variety of large-scale information requiring/benefiting from **"non-traditional" tools** to be processed & analysed
- **Two data sources** relevant for central banks:
  - Restricted view: **the "internet of things"-type** of unstructured data, heavily used by the private sector

  → *Public interest  eg Google Trends, but not really the core*

  - **Large registers, by-products** of 3 types of activities: financial, commercial & administrative

  → *Key issues include confidentiality and quality*

# I – Financial Big Data: … and 4 main types of BD-sets…



# I – Financial Big Data: …with overlaps…

- Increasing part of the **information collected on the web** can be the result of financial, commercial or administrative activities
- Cf recent expansion of "**Fintech**"
  - "*Technology-enabled innovation in financial services that could result in new business models, applications, processes or products with an associated material effect on the provision of financial services*" (FSB, 2017)
  - Parallel innovations: big data, mobile phone, internet, artificial intelligence
- Multiple **applications** that blur traditional boundaries
  - Digital currencies (Bitcoin)
  - Various applications in payments, crowdfunding, smart contracts, robot advice, credit risk assessments & contract pricing



# I – Financial Big Data: … practical issues…

- In practice **CBs deal with various & heterogeneous "big data"**
  - Usually **not directly** produced for a specific statistical purpose, as in the cases of traditional census or survey exercises
  - **Indirectly**, data sources can be exploited for addressing statistical information needs that may independently exist
  - "**Smart data**": treatment of the raw, "organic" data is key
- Public authorities just be at the beginning of making sense of all the **increasing volume and variety of data**
  - Use of specific data sources depend on policy questions
  - Eg payment systems data: of interest to supervisors and tourism analysis



# I – Financial Big Data: … complexity…

- **Micro-level BD universe** is complex and evolves over time
  - Interaction between data available and specific policy needs

- **Transforming data into information** requires
  - **Merging** different sources, with common identifiers
  - Dealing with **inconsistent** observations
  - Choosing a particular **source**
  - **Aggregating**, by using parent relationship and rules
  - Choices may depend on **circumstances** (“time dependency”)



# I – Financial Big Data: … example

- Example: BIS **International Debt Security** issuance statistics
  - Micro aggregation derived from large security-by-security data-sets
  - Data collection based on a "traditional" residency concept…
  - … and a "nationality basis" (include debt issued by foreign affiliates)
- **Constructing nationality-based statistics** requires to
  - Identify the perimeter of global firms
  - Reclassify individual units
  - Consolidate granular information at the group level
  - Tasks both time-dependent and source-dependent

→ Handling large & complex data can benefit from **BD techniques**



# II – Three key developments

- Big Data as a result of the **combination of three key developments in the financial area**
  - The **internet** of things
  - **Digitalisation**
  - Expansion of **micro financial data-sets** in the aftermath of the Great Financial Crisis (GFC) of 2007-09

# II – 3 Developments: Internet of things (1: new data)

- **Significant experience in recent years** in collecting information generated by the wide range of web and electronic devices
  - Search queries, clicks on specific pages, display of information and text online, social media messages…

- Can be **used to complement "standard" statistical processes**
  - In general, the (near) real time availability of web data can allow for getting rapid information and improving timeliness
  - Approach to estimate current patterns and forecast them in advance of actual publication dates (nowcasting exercises)

# II – 3 Developments: Internet of things (2: inflation)

- Example: **"scraping" prices** posted online by retailers
  - Exercises typically limited to specific inflation components (eg volatile fresh vegetables' prices)
  - Process appears robust, scalable and can be automatised
  - Important challenges: capturing unit-level prices, product characteristics, quantities, adequate weights

- **Billion Prices Project** (MIT):
  - Enhanced international comparisons of price indexes
  - Dealing with measurement biases
  - Addressing distortions in international relative prices



# II – 3 Developments: Internet of things (3: house prices)

- Example: collection of **housing prices** on the web
  - Scraping prices displayed by real estate agencies
  - Capturing the various housing characteristics posted in advertisements facilitates the calculation of quality effects (hedonic prices)
- **Challenges**
  - Collecting the information  in a comprehensive & structured way
  - Weighting schemes

→ Particularly relevant for economies with *less developed statistics*

→ In more *advanced countries* also: property prices often derived from low frequency surveys / for a limited number of cities



# II – 3 Developments: Internet of things (4: real activity)

- **Real-side economic indicators**
  - Job web announcements: indicators of business activity & unemployment
  - Monitor consumption of durable goods (eg cars)
  - Overall level of the economy / specific sectors (eg tourism) / areas

- But this use has been relatively **incremental and limited,** even for national statistical agencies in advanced economies, and often targeted at:
  - **Methodological** improvements (eg quality adjustment)
  - Reducing reporting **lags** and data revisions
  - **Alternative** to the organisation of large surveys (eg India)



# II – 3 Developments: Internet of things (5: new insights)

- Possibility of capturing **unsuspected data patterns**
  - "Traditional" statistical modelling to infer economic relationships
  - BD algorithms to incorporate various effects without ex ante assumptions
  - Techniques can be implemented easily and in an automated way
- Opportunity to **incorporate qualitative information**
  - Clicks from web searches, twitter messages or posts on social medias
  - Incorporating sentiment and agents' expectations for measuring risks, changing preferences, causality patterns…
  - Factors that play an important role during crises and are quite difficult to model (non-linearities, network effects)

# II – 3 Developments: Internet of things (6: drawbacks)

- Data **quality issues**
  - Errors, typos and self-fulfilling expectations
  - Need to collect consistent information but goods are not kept identical
  - Announcement prices can differ from actual transaction prices
  - Advertisements remain posted after economic transactions are settled
  - Accuracy of the information that individuals (or robots!) input to the web
  -
- Key limitation is that the data are **not well structured**
  - Details on the location of a transaction / job offer difficult to get
  - Underlying information can be collected several times

# II – 3 Developments: Internet of things (7: challenges)

- **Technical** challenges
  - Use of new techniques (eg web-scraping) and methodologies
- **More fundamental** challenges?
  - Limited interpretability of "black box" calculations
  - Mining data and the need to derive meaningful conclusions from an economic perspective
  - CBs need to present a consistent "story" when communicating policy



# II – 3 Developments: Digitalisation (1: new information)

- **Expanded access** to digitalised information
  - Rise in textual information moving to the web (while not produced by internet activities strictly speaking)
  - Reference documents can be digitalised, accessed and analysed like "web-based" indicators
- Can be more easily and automatically **exploited through ad hoc BD techniques:** eg text semantic analysis
  - Extraction of textual information of interest
  - Characterising text attributes and similarities
  - Classifying information content (eg tone of central banks' messages)
  - Assessing the impact of external factors (eg circumstances, policy actions)



# II – 3 Developments: Digitalisation (2: new opportunities)

- Techniques can also be used to **measure impact** on economic agents' expectations
- Structured way to assess **policy communication**
  - Perceived stance of public authorities' communication
  - Impact of this communication / action in view of the messages expressed in reaction by stakeholders
  - Formation of public expectations

→ **Complement** traditional "event studies" (eg central bank actions)

→ Provides **opportunities** for fine-tuning policy communication



# II – 3 Developments: New financial statistics (1: a revolution?)

- **Revolution in financial statistics** observed since the GFC
  - Limitations of aggregated data: consider those institutions that are systemic on an individual basis
  - Need to measure the distribution of macro indicators, look at "fat tails" and go "beyond the aggregates"
  - Revolution comparable to the 1930s for the real accounts?

- Unprecedented **efforts to collect more** information on the financial sector – the Data Gaps Initiative (DGI) endorsed by G20
  - High demand for large, granular and complex data-sets
  - Collected at the level of institutions, transactions & instruments



# II – 3 Developments: New financial statistics (2: CBs' interest)

- **Fundamental factors explaining why CBs' have been leading the way** for collecting such financial big datasets
  - Go beyond aggregated indicators
  - Make a better use for policy of available/expanding micro-level datasets
  - Realisation that a huge amount of information is already available and could be better exploited (eg administrative data)

- Focus on **very granular information**, derived from various sources, and more complex compared to "typical" web-based data

# II – 3 Developments: New financial statistics (3: CCRs)

- Example: rising **demand for detailed loan-by-loan / security-by-security** information
  - Central credit registries (CCRS) have become the largest data-sets maintained by some central banks
  - Europe's AnaCredit: "analytical credit dataset"
  - US FRBNY Consumer Credit Panel: detailed information on consumer debt and credit derived from individuals' reports
- Data are well structured, but reporting is **highly granular**
  - Multiple attributes:  200 attributes per data point on a monthly basis (and on a daily basis for a subset) for AnaCredit
  - Often complex to aggregate / analyse



# II – 3 Developments: New financial statistics (4: specificities)

- Information often derived from **confidential operations** (tax registers, banks' books)
  - Richness across the population of interest (eg capturing very small enterprises)
  - Usually collected regularly over a long period of time
  - But need for anonymization / confidentiality protection
- **CBs learning from private sector**
  - Increased experience in dealing with large data-sets (eg production of "stress tests")
  - Supervisors of financial firms to develop their expertise in these areas too



# III – Challenges

- **Handling big datasets** requires significant resources and proper arrangements for managing the information
- **Using big data in policy-making** creates opportunities but is not without risks
- Key **implications**
  - Explains why public authorities' actual use of big data is still limited, at least in comparison to the private industry
  - Significant time and effort needed before any regular production of big data-based information for supporting CBs' statistical and analytical work on a large scale

# III – Challenges in handling big data (1)

- **Resources** and proper arrangements for managing BD
  - Sheer size of the data-sets
  - Lack of structure
  - Often limited quality of raw data
- The statistical **production process** itself has to be adapted
  - Work to appropriately collect, clean, reconcile and store BD
  - Usually, BD produced without standard quality controls of "traditional" statistics (while public authorities put a lot of attention on those issues)
  - Significant number of false/inconsistent/missing records

# III – Challenges in handling big data (2)

- Need to **set up a clear and comprehensive information management process**
  - Data acquisition
  - Data preparation
  - Data processing
  - Data validation

- A **major area is IT**
  - Large processing costs, difficult & expensive technology choices
  - Sophisticated statistical techniques: “BD algorithms”, “ML techniques”, “AI”
  - Public authorities with less budget compare to private  sector

# III – Challenges in handling big data (3)

- New issues in terms of **confidentiality protection and security**
  - Large amount of data provided by users through their web-based activities
  - Large financial datasets require the handling of transaction-level, potentially highly confidential, information
  - Data privacy issues may increase with the development of big data and Fintech firms

- Potentially **wider implications**
  - Operational incidents can lead to significant privacy and legal issues, with financial consequences
  - Cf European General Data Protection Regulation (GDPR, 2018)



# III – Challenges in handling big data (4)

- A key risk: **reputation risk**
  - Peculiar position of central banks if private information is reported to them but not protected adequately
  - Especially for regulatory-type data collections
  - But internet-based information, often a by-product of commercial activities, can also pose significant legal, financial, reputational & ethical issues
- **Operational implications**
  - Public statisticians tend to be "cloud computing-adverse"
  - Preference to operate in a "secluded" data environment
  - But could reduce opportunities to use BD techniques in the marketplace



# III – Challenges in handling big data (5)

- Ongoing substantial **internal organisational changes** to deal with big data
  - Cf creation of internal centres for big data statistics, "data lakes", "internal clouds"

- Another key area is **staff**
  - Various skills needed: IT, data science and methodology, legal expertise…
  - A "war for talent"? A competition with the private sector that may be difficult for CBs…
  - Additional issues: compensation, career path, management

# III – Challenges in handling big data (6)

- How to **enhance existing information management processes**?
  - Goal: flexible production of relevant information out of data points
  - "Traditional", template-driven data collections to be replaced by accessing granular data from various sources

- **Requirements**
  - Greater harmonisation of data-sets, statistical standards, identifiers and dictionaries
  - International efforts eg to develop global Legal Entity Identifiers & automated data exchanges standards (XBRL, SMDX, ISO 20022)



# III – Challenges in handling big data (7)

- Better **integration of various IT systems** among both authorities and reporting entities

- Recent "**Fintech innovations**" to facilitate secure data transfer mechanisms:
  - Distributed ledger technology (DLT) to enable network participants to securely propose, validate and record information to a synchronised ledger distributed across the network
  - Each transaction can be recorded in a batch (a "block") and added to the full transactions' history (the "blockchain")

- Involvement of **private service providers ("regtech"** industry)

# III – Challenges in using big data (1)

- Big data **opportunities** for policy use but is not without risks
  - Immediate benefits: lower production costs, new insights, production speed
  - To be balanced against potential large economic and social costs of misguided policy decisions

- **Key question**: does "big data" provide a more accurate picture of economic reality?



# III – Challenges in using big data (2)

- Risk of **conveying a false sense of accuracy** and precision
  - Problem exacerbated by the organic nature of BD:
  - Data often self-reported or by-product of social activities
  - Coverage bias unknown, can be significant (eg social media users)

→ *Extremely **large big data samples may thus compare unfavourably** with (smaller) traditional probabilistic samples – precisely designed to be representative of the population of interest*

→ *Key **misperception** of the intrinsic value of big data*

# III – Challenges in using big data (3)

- Risk of **undermining public policy**?
  - Effectiveness (if data are providing wrong signals)
  - Reputation/legitimacy

- Might systematically **alter decision-making**?
  - Greater ability to monitor the economy in real time: bias towards responding quickly and more frequently to news, encouraging shorter horizons?
  - Greater reliance on "big data"-based analyses of sentiment: risk of excessively fine-tuning policy communication based on perceived expectations rather than actual economic developments?

# IV – Analysing CBs' experiences (1)

- Proper **information management frameworks** needed to make the most of big data so as to:
  - Address challenges faced when handling and using big data
  - Avoid the risk of focussing on cumbersome management tasks – cleaning, documenting, organising data – instead of *using* the information

- Key is to **make sense of the data** collected, with a coherent information management framework

- CBs are following **step-by-step** approaches, with specific use cases instead of "big bang" solutions

# IV – Analysing CBs' experiences (2)

- **Pressing challenges**
  - Combination of internet / digitalisation / new post-crisis initiatives
  - Authorities just at the beginning of making sense of the increasing volume, granularity and variety of information
  - "*Connecting the dots is as important as collecting the dots, meaning the right data*" (Caruana, 2017)
- Fundamental **distinction between "data" and "information"**
  - "Traditional" official statistics were "designed data" collected for a specific purpose
  - By definition were organised in order to extract meaningful information
  - Key difference with "organic"-type big datasets

# IV – Analysing CBs' experiences (3)

- Avoiding the **risk of confusing "data" and "information"**
  - Need to complement, not replace, designed data with (organic) BD sets
  - Calls for ensuring a continuum: from the collection of BD to statistical processing and the extraction of valuable information for policy use

- Various **ingredients**:
  - Proper IT infrastructure
  - Adequate statistical applications (including big data analytics)
  - Legal and HR support in terms of skill-sets
  - Good co-ordination to have a consistent and holistic information production chain



# IV – Analysing CBs' experiences (4)

- Central banks have **already started to rethink** their information management processes to:
  - Be able to access internet data-sets and big data techniques
  - Handle the new data collections initiated after the GFC

- **No one-size-fits-all approach**, as it depends on
  - Characteristics of each data collection
  - Country circumstances
  - Actual policy needs



# Annex (1): Selected references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# Annex (2): Selected BD projects by central banks

| Big data areas | Types of data-sets | Examples of projects |
|---|---|---|
| Administrative records | Foreign trade operations / investment transactions | Balance of payments statistics eg tourism, exports |
| | Taxation / payroll / unemployment insurance | Employment, wages, business formation (SMEs) |
| | Central balance sheet offices | Performance vulnerabilities assessment |
| | Loans registers | Measurement of credit risk, FX exposures |
| | Financial market supervisors | Network analysis, exposures |
| | Public financial statements | Corporate balance sheet, group-level supervision |
| | Financial market activity indicators | Payments systems, Trade repositories |
| Web-based indicators | Internet clicks | Google searches |
| | social networks | confidence & economic sentiment |
| | Digitalised content / text | policy communication , analysis of expectations |
| | Websites' scraping | Various uses |
| | Job portals | Employment / activity |
| | Prices posted directly on websites | Measure specific components of the CPI, PPIs, Inflation nowcasting / forecasting, Pricing strategy analysis |
| | Real estate agencies | House price indices |
| Commercial data-sets | Credit card operations | Payments patterns, Tourism |
| | Mobile operators | Mobile positioning data (eg travelers'), Financial inclusion |
| | Geo spatial information | National statistical system Tasks |
| Financial data-sets | Credit institutions | Balance sheet exposures, Investor behaviour/expectations |
| | Settlement operations | Operational risks, Market functioning |
| | Securities issuance | Security-by-security databases |
| | Market liquidity | Bid/ask spreads |
| | Custodians records | Securities holding statistics |
| | Tick-by-tick data | Real-time analysis of financial patterns |

Thank you!!

Questions?

bruno.tissot@bis.org

IFC.secretariat@bis.org