Managing Confidentiality and Provenance across Mixed Private and Publicly-Accessed Data and Metadata

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Introduction

NCRN

- This work is part of the NSF Census Research Network (NCRN) - Cornell Node ("Integrated Research Support, Training and Data Documentation")
- Funded by NSF Grant #1131848.
- For more information, see www.ncrn.cornell.edu.
Overview of work

- Basic program outlined in Abowd, Vilhuber, and Block (PSD 2012) [3] and Lagoze, Block, Williams, Abowd, and Vilhuber, (IDCC 2013) [8]

- PROV extension described in more detail in Lagoze, Williams, Vilhuber (Metadata and Semantics Research Conference, November 2013) and Lagoze et al (European DDI User Conference, December 2013) [9]
Introduction

Some facts that motivated us

Stating the problem in the U.S. case

CED$^2$AR: A proposed solution
   What is DDI
   DDI extension for confidentiality protection
   DDI extension for provenance tracing
Critical element of science

- Replication of methods, data inputs, computational environment is a critical element of the scientific approach
- Journals, funding agencies (in the U.S.) have been moving to making archiving of inputs to scientific results more robust, even mandatory
Econometrica

“In its first issue, the editor of Econometrica (1933), Ragnar Frisch, noted the importance of publishing data such that readers could fully explore empirical results. Publication of data, however, was discontinued early in the journal’s history. [...] The journal arrived full-circle in late 2004 when Econometrica adopted one of the more stringent policies on availability of data and programs.

Increased use of restricted-access data

- Today’s young scholars pursue research programs that mandate inherently identifiable data
  - Geospatial relations,
  - Exact genome data,
  - Networks of all sorts,
  - Linked administrative records
- These researchers acquire authorized, generally unfettered, restricted access to the confidential, identifiable data and perform their analyses in secure environments.
- Archiving (curation) of input data is complicated
- Knowledge discovery is complicated
Decline in the use of classic public-use data

Use of Pre-Existing Survey Data in Publications in Leading Journals, 1980-2010

Note: "Pre-existing survey" data in the figure includes surveys such as the CPS at BLS and does not include surveys designed by researchers for their study. Sample excludes studies whose primary data source is from developing countries.

Vilhuber, Abowd, Block, Lagoze, Williams

Data Management of Confidential Data
Increase in the use of administrative data in economics

Use of Administrative Data in Publications in Leading Journals, 1980-2010

Note: Administrative data refer to any data that was collected without directly surveying individuals (e.g., scanner data, stock prices, school district records, social security records). Sample excludes studies whose primary data source is from developing countries.

Vilhuber, Abowd, Block, Lagoze, Williams
Nature, 2012

“Many of the emerging ‘big data’ applications come from private sources that are inaccessible to other researchers. The data source may be hidden, compounding problems of verification, as well as concerns about the generality of the results.”

(Huberman, Nature 482, 308 (16 February 2012) doi:10.1038/482308d)

Other domains

- Biology (genetics data, chemical compounds)
- Computer science (search records, single-firm examples)
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CED$^2$AR: A proposed solution

What is DDI

DDI extension for confidentiality protection

DDI extension for provenance tracing
Why we think there is a problem

Core issues

a. Insufficient curation (starting with archiving)
b. No way to reference data (unique identifiers)
c. No consistent way to learn about the data (metadata dissemination)
d. Weak or non-existent provenance tracing
Generalized problem

Multiple data sources in the US

- U.S. Census Bureau (RDC)  ▶ more
- Internal Revenue Service (confidential, public-use) ▶ more
- Bureau of Labor Statistics (confidential, public-use data) ▶ more

Present elsewhere?

- Canada:
  - Centre for Data Development and Economic Research (CDER: RDC-like for business data) ▶ more
  - better: Canadian RDC network ▶ more
- France: Réseau Quetelet ▶ more, Centre d’accés sécurisé distant aux données (CASD)
- Germany: IAB
Introduction

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CED$^2$AR: A proposed solution

What is DDI

DDI extension for confidentiality protection

DDI extension for provenance tracing
Comprehensive Extensible Data Documentation and Access (CED²AR)

Core
We develop the core of a method for solving the data archive and curation problem that confronts the custodians of restricted-access research data and the scientific users of such data. Our solution recognizes the dual protections afforded by physical security and access limitation protocols, and allows for much improved provenance tracing.
Proposed solution

Extensible framework

- Based on existing standards (Data Documentation Initiative, DDI) with extension to accommodate disclosure protection mechanisms and provenance tracing
Proposed solution

Extensible framework

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- Connectors (import/export) to other sources and standards
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What is DDI?
Example of DDI

<?xml version="1.0" encoding="UTF-8" ?>
<codeBook xmlns="ddi:codebook:2_5">
<docDscr>
<citation>
  <titlStmt>
    <titl>SIPP_Synthetic_Beta</titl>
    <altTitl>SSB</altTitl>
    <IDNo agency="DOI">TBD</IDNo>
  </titlStmt>
  <rspStmt>
    <AuthEnty affiliation="Cornell University">
      Virtual RDC
    </AuthEnty>
  </rspStmt>
</citation>
</docDscr>
</codeBook>
..better seen as
Survey of Income and Program Participation (SIPP) 2004 Panel (ICPSR 4517)

Principal Investigator(s): United States Department of Commerce. Bureau of the Census

Summary:
This data collection is part of a longitudinal survey designed to provide detailed information on the economic situation of households and persons in the United States. These data examine the distribution of income, wealth, and poverty in American society and gauge the effects of federal and state programs on the well-being of families and individuals. There are three basic elements contained in the survey. The first is a control card that records basic social and demographic characteristics for... (more info)

Series: Survey of Income and Program Participation (SIPP) Series

Access Notes
- These data are freely available.

Dataset(s)

WARNING: Because this study has many datasets, the download all files option has been suppressed, and you will need to download one dataset at a time.

WARNING: This study is over 150MB in size and may take several minutes to download on a typical internet connection.
Expanded DDI attributes

**Standard DDI**

Fragment of variable description*

```xml
<var ID="V1" dcml="0" files="F1" intrvl="discrete"
  name="cur_end mar_flag">
  <location width="12"/>
  <labl>Flag: Linked marriage ended</labl>
  <valrng>
    <range UNITS="REAL" max="2" min="0"/>
  </valrng>
  <sumStat type="vald"> 123 </sumStat>
  <sumStat type="invd"> 456 </sumStat>
  <catgry>
    <catValu> 1 </catValu>
    <catStat type="freq"> 234 </catStat>
  </catgry>
</var>
```

* All values are fake

Vilhuber, Abowd, Block, Lagoze, Williams

Data Management of Confidential Data
Expanded DDI attributes

Standard DDI
Fragment of variable description*

```xml
<!--var ID="V1" dcml="0" files="F1" intrvl="discrete"
name="cur_end mar_flag">
  <location width="12"/>
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</var>
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<catgry>
  <catValu> 1 </catValu>
  <catStat type="freq"> 234 </catStat>
</catgry -->
```

* All values are fake

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Expanded DDI attributes

Standard DDI

Fragment of variable description*

<!--var ID="V1" dcml="0" files="F1" intrvl="discrete"
name="cur_end_mar_flag">
  <location width="12"/>
  <labl>Flag: Linked marriage ended</labl>
  <valrng>
    <range UNITS="REAL" max="2" min="0"/>
  </valrng -->
  <sumStat type="vald"> 123 </sumStat>
  <sumStat type="invd"> 456 </sumStat>
<!-- catgry>
  <catValu> 1 </catValu>
  <catStat type="freq"> 234 </catStat>
</catgry -->

* All values are fake
Expanded DDI attributes

Enhanced DDI
Re-using existing attribute, but expanding scope.

```xml
<var ID="V1" dcml="0" files="F1" intrvl="discrete"
name="cur_end mar_flag">
  <location width="12"/>
  <labl>Flag: Linked marriage ended</labl>
  <valrng access="release">
    <range UNITS="REAL" max="2" min="0"/>
  </valrng>
  <sumStat access="restricted" type="vald">123</sumStat>
  <sumStat access="restricted" type="invd">456</sumStat>
  <catgry access="release">
    <catValu access="release">1</catValu>
    <catStat type="freq" access="restricted">234
  </catgry>
</var>
```

* All values are fake

Vilhuber, Abowd, Block, Lagoze, Williams

Data Management of Confidential Data
Enhanced DDI
Allows for verifiable filtering*

```xml
<var ID="V1" dcml="0" files="F1" intrvl="discrete"
name="cur_end mar_flag">
  <location width="12"/>
  <labl>Flag: Linked marriage ended</labl>
  <valrng access="release">
    <range UNITS="REAL" max="2" min="0"/>
  </valrng>
</var>

* All values are fake

Vilhuber, Abowd, Block, Lagoze, Williams
## Application to confidentiality protection

### Browse all Variables

Searching Synthetic Longitudinal Business Database  Uncheck any variables to be released, then press [SAVE].

Show 10 variables

<table>
<thead>
<tr>
<th>Confidential</th>
<th>Variable Name</th>
<th>Label</th>
<th>Codebook</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>act</td>
<td>dropped Activity Code</td>
<td>Synthetic Longitudinal Business Database</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>cbp</td>
<td>dropped</td>
<td>Synthetic Longitudinal Business Database</td>
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<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>firstflag</td>
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<td>Synthetic Longitudinal Business Database</td>
</tr>
<tr>
<td></td>
<td>firstyear</td>
<td>synthetic First Year Establishment is Observed</td>
<td>Synthetic Longitudinal Business Database</td>
</tr>
</tbody>
</table>

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Data Management of Confidential Data
Options

- Variable is suppressed, including all subordinate elements
- Variable description is released, but all subordinate statistical elements are suppressed (attribute of \(< \text{var} >\) set to “released”) [default]
- Expand all existing attributes, individually select subordinate elements to suppress (attribute of sub-element is set to “suppressed”, content suppressed)
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Data Management of Confidential Data
Definitions

- First draft of specification in test use by our team
Definitions

- First draft of specification in test use by our team
- Full enhanced specification (based on DDI-Codebook 2.5) published on CED$^2$AR
Definitions

- First draft of specification in test use by our team
- Full enhanced specification (based on DDI-Codebook 2.5) published on CED²AR
- Enhanced specification proposed to DDI Alliance
Implementation

Definitions

- First draft of specification in test use by our team
- Full enhanced specification (based on DDI-Codebook 2.5) published on CED²AR
- Enhanced specification proposed to DDI Alliance
- Expand to DDI-Lifecycle
The provenance problem

“data provenance, one kind of metadata, pertains to the derivation history of a data product starting from its original sources” [...] “from it, one can ascertain the quality of the data base and its ancestral data and derivations, track back sources of errors, allow automated reenactment of derivations to update the data, and provide attribution of data sources”

Support in DDI

Provenance and Metadata
Not (currently) a “native” component of DDI, closest thing is:

```xml
<xs:complexType name="othrStdyMatType">
  <xs:complexContent>
    <xs:extension base="baseElementType">
      <xs:sequence>
        <xs:element ref="relMat" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="relStdy" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="relPubl" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element ref="othRefs" minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

Downside
No structure. Mostly verbose entries.
Only a verbose description

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Data Management of Confidential Data
UK Data Archive example

**SERIES ABSTRACT**

The Family Expenditure Survey (FES), which ran from 1961-2001, was a continuous annual survey that provided information on household and personal incomes, certain payments that recurred regularly (e.g. rent, gas and electricity bills, telephone accounts, insurances, season tickets and hire purchase payments), and included a detailed 14-day expenditure record. From 2001, the both the FES and the National Food Survey (NFS) were replaced by a new survey, the Expenditure and Food Survey (EFS), which subsequently became the Living Costs and Food Survey (LCF) from 2008.

**DATA ACCESS**

GN 33057 | FAMILY EXPENDITURE SURVEY, 1961-2001

**RELATED RESOURCES**

Related studies:

Family Resources Survey, 1979 (SN 1930)

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PROV model
W3C PROV Model based in the notions of

1. **entities** that are physical, digital, and conceptual things in the world;

2. **activities** that are dynamic aspects of the world that change and create entities; and

3. **agents** that are responsible for activities.

4. a set of **relationships** that can exist between them that express attribution, delegation, derivation, etc.
Incorporating PROV (LBD)

LBD Provenance

Business Register (SSEL)

- Enumerated frame
- New establishments
- Sample frame

Economic Census (quinquennial)

- Possible linkage

Longitudinal Business Database (LBD)

- Some exclusions

County Business Patterns (CBP)

Annual Survey of Manufactures (ASM)

- Possible linkage

Synthetic LBD (SynLBD)

Business Dynamics Statistics (DDS)

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Data Management of Confidential Data
entity(cdr:LBD, [prov:type='cdr:dataset', prov:label='Longitudinal Business Data'])
entity(cdr:synthLBD, [prov:type='cdr:dataset', prov:label='Synthetic LBD'])
entity(cdr:BR, [prov:type='cdr:dataset', prov:label='Business Register'])
entity(cdr:cbp, [prov:type='cdr:dataset', prov:label='County Business Patterns'])
entity(cdr:asm, [prov:type='cdr:dataset', prov:label='Annual Survey of Manufacturers'])
entity(cdr:ec, [prov:type='cdr:dataset', prov:label='Economic Census'])
entity(cdr:jm, [prov:type='prov:Plan', prov:label='Jarmin Miranda 2002'])
entity(cdr:synthPlan, [prov:type='prov:Plan', prov:label='synthetic plan'])
entity(cdr:tax, [prov:type='cdr:dataset', prov:label='IRS Tax Records'])

agent(cdr:USCB, [prov:type='prov:Organization', prov:label='US Census Bureau'])
agent(cdr:CES, [prov:type='prov:Organization', prov:label='Center for Economic Studies'])
agent(cdr:IRS, [prov:type='prov:Organization', prov:label='Internal Revenue Service'])
agent(cdr:autoMatch, [prov:type='prov:SoftwareAgent'])
agent(cdr:SAS, [prov:type='prov:SoftwareAgent'])
agent(cdr:ESMPD, [prov:type='prov:SoftwareAgent',
                    prov:label='Economic Statistical Methods and Programming Division'])

activity(cdr:synth, [prov:label='anonymize'])
activity(cdr:aggr, [prov:label='aggregate'])
activity(cdr:procLBD, [prov:label='process LBD'])
activity(cdr:ad, [prov:label='aggregation/disclosure protection'])
activity(cdr:asmSurvey, [prov:label='ASM Survey'])
activity(cdr:ecs, [prov:label='economic census survey'])
The key PROV element embedded as DDI/XML

```xml
<stydDscr> <!-- Standard DDI 2.5 -->
<othrStdyMat> <!-- Standard DDI 2.5 -->
<relStdy> <!-- Standard DDI 2.5 -->
  <!-- From here, PROV additions -->
  <prov:wasDerivedFrom>
    <prov:generatedEntity prov:ref="cdr:LBD"/>
    <prov:usedEntity prov:ref="cdr:BR"/>
  </prov:wasDerivedFrom>
  <prov:wasAssociatedWith>
    <prov:activity prov:ref="cdr:procLBD"/>
    <prov:agent prov:ref="cdr:CES"/>
    <prov:plan prov:ref="cdr:procLBDPlan"/>
  </prov:wasAssociatedWith>
</relStdy> <!-- Standard DDI 2.5 -->
</othrStdyMat> <!-- Standard DDI 2.5 -->
</stydDscr> <!-- Standard DDI 2.5 -->
```

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Additional PROV elements
These could be derived from existing DDI elements (still being developed)

<!-- Entities -->
<prov:entity prov:id="cdr:BR">
   <dct:title>Business Register</dct:title>
</prov:entity>

<!-- Plans = Methodology -->
<prov:plan prov:id="cdr:procLBDPlan">
   <prov:location xsi:type="xsd:anyURI">
      http://ideas.repec.org/p/cen/wpaper/02-17.html
   </prov:location>
   <prov:type>prov:Plan</prov:type>
</prov:plan>
More details forthcoming

- Lagoze, Williams, Vilhuber, Block “Encoding Provenance of Social Science Data: Integrating PROV with DDI”, accepted for 5th Annual European DDI User Conference (December 2013)
Usage scenario

CED²AR
The Comprehensive Extensible Data Documentation and Access Repository

Search

Searching Longitudinal Business Database, National QWI, Synthetic Longitudinal Business Database

employment

Advanced Search

Show 10 variables

Filter by Codebook

Compare Variables

No variables selected

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Data Management of Confidential Data
Usage scenario
## Usage scenario

### CED²AR

The Comprehensive Extensible Data Documentation and Access Repository

<table>
<thead>
<tr>
<th>Name</th>
<th>Label</th>
<th>Description</th>
<th>Concept</th>
<th>Codebook</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>emp</strong></td>
<td>March 12 Employment</td>
<td></td>
<td></td>
<td>Longitudinal Business Database</td>
</tr>
<tr>
<td><strong>qwi_f</strong></td>
<td>QWI: FQ employment</td>
<td></td>
<td></td>
<td>National QWI</td>
</tr>
<tr>
<td><strong>emp</strong></td>
<td>(synthetic) March 12 Employment</td>
<td>Paid employment consists of full and part-time employees, including salaried officers and executives of corporations, who we... more</td>
<td></td>
<td>Synthetic Longitudinal Business Database</td>
</tr>
</tbody>
</table>
### Highlighting provenance

**Name** | **Label** | **Description** | **Concept** | **Codebook** | **Proximity**
--- | --- | --- | --- | --- | ---
emp | March 12 Employment | Paid employment consists of full and part-time employees, including salaried officers and executives of corporations, who we... more | Synthetic Longitudinal Business Database | | LBD
qwi_f | QWE FQ employment | | National QWI | | SynLBD
emp | (synthetic) March 12 Employment | | Longitudinal Business Database | | National QWI
CED$^2$AR next steps

- Formalize the DDI extension
CED²AR next steps

- Formalize the DDI extension
- Provide implementation outside of Census Bureau
CED$^2$AR next steps

- Formalize the DDI extension
- Provide implementation outside of Census Bureau
- Test implementation within the Census RDC
Thank you

- [3] for more details
- Labor Dynamics Institute
- VirtualRDC @ Cornell
- NCRN Cornell website
Extra slides

Census Bureau
IRS
BLS
CDER
CRDC
France
1,505 project-dataset pairs

Many projects use multiple datasets.
Economic (business) datasets

- 71% of datasets are business (economic) datasets
- Primarily establishment-based records from the Economic Censuses and Surveys, the Business Register, and the Longitudinal Business Database (LBD)
- They form the core of the modern industrial organization studies [5, 11] as well as modern gross job creation and destruction in macroeconomics [4, 6].
- But there are no public-use micro-data for these establishment-based products
- Exception: recently-released Synthetic LBD [2, 7]
- Currently no active curation (of derived datasets) [a], no way to reference [b], convoluted way to learn about the data structure [c*]
Linked employer-employee data

- Longitudinal and cross-sectional detail
- New confidentiality protection methodologies [1, 10] have unlocked large amounts of data for public-use: highly detailed local area tabulations exist based on the LEHD data
- But: no public-use micro-data exist for this longitudinal job frame or any of its derivative files.
- Confidential data are dynamic (quarterly changes)
- Currently some active curation (archiving, 10-yr!) [a*], no way to reference (publicly) [b*], convoluted way to learn about the data structure [c*]
New projects (Chetty et al, 2012; von Wachter and co-authors) have created and/or used linked longitudinal data at the IRS or the Social Security Administration.

Neither agency has long-run experience at the statistical data curation function [a], (meta)data dissemination [b,c].

Although both IRS and SSA have produced statistical tables for a long time.
Bureau of Labor Statistics

- Long history of making time-series available
- Limited access to microdata at the BLS
- Unknown curation [a]
- Even for public-use data, no way to reference specific releases [b]
- No well-established way to learn about microdata [c]
Data Sets

A number of business micro databases can be accessed at CDER. Key databases are listed below.

For more documentation on each of the databases, or documentation on other databases, please contact CDER at cder@statcan.gc.ca.

- Annual Survey of Manufacturing
- Annual Survey of Manufacturing – Export and Import Registry Database
- Canada Border Service Agency Customs Database
- Capital and Investment Program
- Longitudinal Employment Analysis Program
- Longitudinal Worker File
- National Accounts Longitudinal Microdata File
- T2-LEAP
- T2-LEAP-Export and Import Registry Database
- Survey of Financing of Small and Medium Enterprises
- Survey of Innovation and Business Strategies
- Workplace Employee Survey

Annual Survey of Manufactures (ASM)

The ASM is a survey that covers all manufacturing locations together with associated head offices, sales offices and auxiliary units which have been classified to the manufacturing industries. Details include include the period financial statements, cost of materials and supplies used, cost of energy consumed, and employment of workers by sex and age.
Surveys available in the RDCs

The following data sets are currently available at the RDCs. For additional sources of data please refer to Statistics Canada Products and Services.

To read a short description about a specific survey used at the RDCs, click on the survey details.

To access detailed documentation on a specific survey used at the RDCs, click on the appropriate cycle or year. Many of the surveys below have multiple cycles. The links below will take you to the most recent cycle or wave released. Please select "Other reference period" in the "Definitions, Data Sources and Methods Pages" for links to documentation for the earlier cycles.

<table>
<thead>
<tr>
<th>Record Number</th>
<th>Survey Name</th>
<th>Acronym</th>
</tr>
</thead>
<tbody>
<tr>
<td>5108</td>
<td>Aboriginal Children's Survey</td>
<td>ACS</td>
</tr>
<tr>
<td>3250</td>
<td>Aboriginal Peoples Survey</td>
<td>APS</td>
</tr>
<tr>
<td>3879</td>
<td>Adult Education and Training Survey</td>
<td>AETS</td>
</tr>
<tr>
<td>3207</td>
<td>Canadian Cancer Registry</td>
<td>CCR</td>
</tr>
<tr>
<td>3226</td>
<td>Canadian Community Health Survey - Annual Component</td>
<td>CCHS</td>
</tr>
<tr>
<td>5015</td>
<td>Canadian Community Health Survey – Mental Health</td>
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<td>Canadian Community Health Survey - Nutrition</td>
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<td>Canadian Tobacco Use Monitoring Survey</td>
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<td>4508</td>
<td>Census of Population - Additional documentation</td>
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<td>3504</td>
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<td>EDS</td>
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<tr>
<td></td>
<td>Survey of Familyブランド</td>
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</tr>
</tbody>
</table>

Vilhuber, Abowd, Block, Lagoze, Williams: Data Management of Confidential Data
... but also not perfect

Attempt to access data information on General Social Survey

Access forbidden! / Accès interdit !

Access forbidden DLI!

This web module may only be accessed from the institutional networks of Canadian postsecondary institutions participating in the Data Liberation Initiative (DLI). If you are a student or a member of a participating institution and you are unable to access these pages through your institutional network, please inform the DLI contact at your institution.

Accès interdit IDD !

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