Weaving the economic Linked Open Data

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***Abstract*— Efforts in integrating the basic economic functions under a common or compatible context could be accelerated by enabling semantic processing of the underlying data. We establish the basic flows among public budgeting, contracting and spending with business information and provide the necessary ontological elements that would integrate them in economic Linked Open Data corpus.**

***Index Terms*—Linked Open Data, e-Procurement, public spending, semantic and social web**

I. Introduction

The integration of economic functions within and among economies has been recognized as a driver for development. Eurozone and the Strategy for a European Single Market [1] are among the initiatives that are based on orchestrating a set of common or compatible economic functions. In parallel, a series of important efforts has emerged in the domain of opening and linking government data (see for instance [2]). A part of this data includes economic data such as public budgets and spending, calls for tenders, business registries and financial statements. The question is how can we create a bidirectional flow between the endeavours for economic Linked Open Data (LOD) and integrated economic processes. We address the above issue by providing the ontological framework for interlinking open data with regards to public budgeting and spending, e-procurement and business information. The paper is organized as follows. Section II provides a very brief review of the efforts in opening and linking economic data. Section III analyses public budgeting and spending as a cyclical economic process within the LOD corpus. Section IV describes the constituents of the proposed ontological engineering. Section V concludes.

II. Economic Linked Open Data: The Story So Far

Linked data are becoming the dynamic force of change in the Web economy [3]. Publishing as Linked Data enables *"Publish once, use many times"*. Linked Data is published in context, giving both the value and the "meaning" of the data. Different consumers can extract different slices of the data for different purposes. Network effects arise in Linked Data by enabling web users to build bidirectional and massively processable interconnections among online data and second, by re-using and adding value in the existing infrastructure in the government and business spheres [4]. The increasing effort to publish economic data as LOD stems from two sources: international organizations (e.g. World Bank, OECD etc.) and governments. Economic LOD include information about economic indicators and statistics, public budgets and spending, calls for tenders and business repositories. Still the majority of economic information remains either in proprietary form (e.g. ebr.org) or fragmented behind technological and institutional barriers. The underlying business models for publishing economic LOD are in their infancy and a small number of applications exist in the market. In order to promote innovation and create a viable market for LOD applications, the public sector should initiate the virtuous cycle of publication since it produces and controls the core of economic LOD. As it happened in the inception of the web itself, market is not capable of undertaking the entire cost and the associate risk of building the necessary infrastructure for LOD. The following sections are devoted in describing the basic components of economic LOD that can serve as "public infrastructure" for both data publishers and business across the market spectrum.

III. Public Budgeting and Spending as Economic LOD

The present paper is focused in framing the links of public budgeting and spending to e-procurement and related business information. To briefly describe the particular information cycle, governments publish budgets, parts of which create projects that result in calls for tenders. Once tenders are fulfilled and projects are assigned, funds are transferred. Spending data can be used to assess the completion of public budgets. This cyclical flow generates data that, if published openly, makes the whole process tractable and analyzable. In this context, post-cycle analysis can help improve the next cycles with respect to their quality and effectiveness, among others. Furthermore, the deployment of LOD and the use of ontologies throughout the cycle make possible the deployment of semantic web services, automation and various forms of reasoning. Finally, since these technologies are web-oriented, there is feedback coming from web 2.0 sources by users that can also be used in improving the process. Thus, part of the generated information is a direct derivative of social content creation and annotation. In the following section we analyse the components and flows in this part of economic LOD.

A. Description of Components

1) Government Budget

A budget is generally considered as a systematic collection of planned revenues and expenses. More formally, "*A budget is a plan for the accomplishment of programs related to objectives and goals within a definite time period, including an estimate of resources required, together with an estimate of resources available, usually compared with one or more past periods and showing future requirements.*" [5]. Government budget is a specific type of budget that refers to the expenses and revenues plan of a public authority. Part of the expenses is referred to projects that are outsourced to the private sector. Typically, the awarding procedure involves a public call for tenders under a certain legal and time framework. Consecutively, the payments and auditing of public works follows complex public accounting procedures. There is not a unique global standard for forming public budget accounts.

Seen as an information resource, a government budget can be associated with functional as well as non-functional metadata. Examples of *non-functional* metadata include the authority of origin (e.g. central/local government), publication details and authorship, languages, URIs and so on. Examples of *functional* metadata include total amounts, details on the associated period of time (such as the associated fiscal year), as well as properties linking the budget to a breakdown of categories, projects and potential beneficiaries. Expenses and revenues can be considered as items (resources) that are linked to a particular budget, each one associated with their own set of metadata. These items are linked via partonomic relationships with a budget resource.

2) Calls for Tenders

An *expense item*, as described earlier, is assumed to be associated with a means of materialization, in the sense that there needs to be a way for a budget's expense item to be realized into the physical world. In the case of competitive assignment, this is done via *calls for tenders*, which are in turn linked to unassigned (offered) contracts. A call for tenders is associated with information concerning the nature of the contest, the professional prerequisites that need to be satisfied, as well as information associated with the call's authorship, tender deadline, publication dates etc. A call for tenders is associated with a particular contract resource that needs to be fulfilled. The contract resource carries information associated with the proposed project, such as the project requirement analysis, the business classification of the project, as well as the description of what kind of service or product must be delivered. As in the case of public budgeting, call for tenders are not following a uniform standard. For instance, in the European Union calls for tenders are published in ted.europa.eu in accordance with the Common Procurement Vocabulary (CPV) for business sectors and the Nomenclature of territorial units for statistics (NUTS) classification for regions. On the contrary, the United States follows the North American Industry Classification System (NAICS) and the United Nations the United Nations follows the Standard Products and Services Code (UNSPSC). For a comparative analysis of product classification schemata, see [6].

3) Spending

Every public contract has associated outgoing payments from the account of contracting authority to the awardee. Under the above context, spending can be materialized by spending items such as payment decisions and payment resources. The difference between spending items and tenders is that the existence of a spending item presupposes that a transfer of funds or other financial resources has already and officially taken place between several parties, in regard with a particular expense item, as explained earlier. A payment resource is linked to one or more contracts that are signed after a particular tender is accepted. It contains information about payers, payees, payment categories, as well as descriptive data that have to do with the spending action (e.g. publicspending.gr ontology [7]).

4) Business Information

Business information related to the budget and procurement flows is published through business registries and financial statements.

i) Business Registries

Business registries are used as official information repositories. Commonly, in most jurisdictions businesses need to be registered in their local business registries in order to be legally able to start operations. Information related to their activity (usually according to a particular standard, such as *Classification of Products by Activity,* or in short CPA), names and addresses, as well as legal forms, among others, has to be provided in the registry. The official business registries are only updated by public agencies through formal procedures, thus making the information associated with them mostly static or slowly changing.

ii) Financial Statements

In some cases, eligibility in a call for tenders presupposes a minimum threshold for specific financial indicators such as turnover and profits. These prerequisites are proved through the financial statements of the postulant business. In any case, payments to businesses that are related to public works are audibly reported in financial statements. Briefly, a financial statement of a business enterprise is a formal report, which is structured according to a standardized form and presents the main financial activities in a specific time frame. For most types of business enterprises, financial reporting is mandatory. There are many different country and industry specific methodologies for accounting that have been partially standardized in global level under the International Financial Reporting Standards (IFRS) [8].

B. Cyclical Process

In the public expenditure economy, the flow of information between budgets, tenders and spending is assumed to be cyclical. This is meant in the sense that each iteration provides new knowledge for the next iteration, either in the form of feedback or in the form of knowledge maturation. Feedback comes from external commenting, assessing, evaluating or mere acknowledging, whilst maturation comes from enriching the existing knowledge with facts that had not been brought to light earlier but have been highlighted by the process (Figure

1). Tenders and spending, ideally interact with business information, both inwards and outwards. The process of evaluating tenders, as well as mapping spending to companies are supported by the open business information repositories. These repositories are in turn updated by the new knowledge about tenders and spending. Users seen in Figure 1 can be either actively or passively involved. Active users are businesses, governments, public authorities and anyone who has the power to influence the internal workings of the cycle, whereas passive users have the form of reviewers, researchers and related parties that consume the generated information for external purposes.

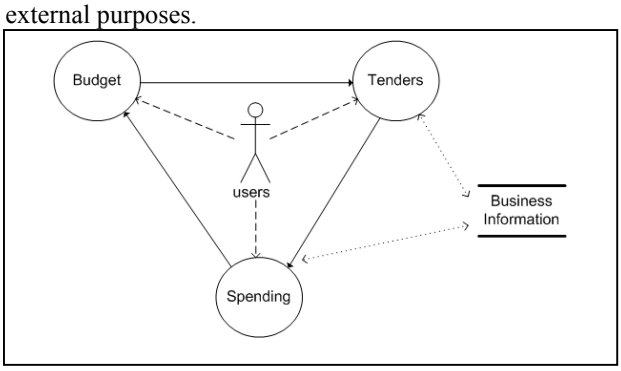

Figure 1: The lifecycle of public expenditure that is outsourced by private business.

C. Information Flow vs. Financial Flow

The flow depicted in Figure 1 is made up in reality of two constituents, namely the *information* and the *financial* flow. The information flow is relevant to the LOD/Semantic Web level. It describes the process of how data are used as input and output in the different processes and activities, as well as how existing information is used to create new information. It represents the overall interactions and data exchanges between the different information components within the cycle. Within various cycles of the information flow, data is created, openly published, linked with existing open data (in the form of LOD), and reused. On the other hand, the financial flow describes how funds (and possibly other financial resources) are circulated. The cardinality is not assumed to be 1:1 in every directed arrow of the flow, as there is no guarantee that every fund that is accounted for during one activity will be manifested financially in the following activity. For instance, some of the tenders might not get realized or signed contracts exceed their budget. Nevertheless, this loss results in the creation of interesting statistical data that become part of the information flow. These data can be used for post-cycle analyses and evaluation of the economic process in general, as well as case and business sector-specific analysis on effectiveness. At the financial level, the flow of funds from Budget to Tenders is not expected to be 100% in accordance with the expenses envisioned in the initial budget. However, given that the whole procedure becomes tractable in open data format, the missing funds give insights as well as useful statistics on how effective the execution of budgetary plans actually is. The same can be said for the financial flow between Tenders and Spending, where a percentage of contracts might not be fulfilled for various reasons. In this modelled part of economic LOD, the cyclical nature of the information flow as well as the feedback component attributes an overall degree of open control and accountability over the data that is not present with the current hardcopy-based bureaucratic models.

IV. Open Data and Ontology Engineering

In this section, we review the current status of (linked) open data for each component of the cycle. Furthermore, we will identify the basic ontological components, from both new and existing ontologies, that are used to represent each domain.

A. Government Budget

1) Open Data

Even though it is not standard practice yet for governments to publish their budget in open data formats, most countries publish their budget data on the web as static files in human-readable forms, thus creating a range of heterogeneous repositories that need further processing in order to be analysable and reusable. Apart from central governments, several local authorities provide online their associated budget data. In the semantic part, there has been little to no work carried out in the field of ontology development for universal description of budgets. For an attempt on conceptualizing the budget domain see [9]. This is mainly due to the fact that there are limited official linked open data initiatives to describe published budgets, and most of the available data comes from a-posteriori processing of non-machine-understandable data, such as PDF documents or unstructured websites.

2) Ontological Components of the Budget sub-domain

Brusa et al [9] identify the key concepts and relations that describe a budget, such as budget status (e.g. approved, pending etc.), programmatic category (e.g. program, sub-program etc.), as well as related concepts such as fiscal year, sector and so on. Following a similar ontology engineering logic, we can identify the main and most general ontological components related to budgets as follows in Table 1.

Ontological Component	**Type**
Budget	Concept
Budget document	Concept
Budget status (approval, closure, formulation, execution)	Concept
Expense item	Concept
Revenue item	Concept
Publishing authority	Relation (FOAF, DBpedia etc.)
Source of finance	Relation (FOAF, CBV etc.)
Revenue/Expense item classificat.	Relation (CPV, NAICS etc.)
Amendment hist./Budget versioning	Relation (link to other budget items)
Non-functional metadata	Relations (via Dublin Core)

Table 1: Main ontological components and relations to external ontologies.

The points at which budget data can become linked data are traced in the following connections:

- Expense program categories (through classification schemas such as CPV, NAICS etc.)
- Geographical locations (Geonames, DBpedia)
- Authorities with linked data representations, such as governments, ministries and individuals (DBpedia, FOAF, opencorporates)

Often budget data are used to create public expenditure (spending) data, which is then used for analysis and visualizations. The resulting information can only be considered as a rough estimation of actual public expenditure. In order for useful information to be derived, expenditure information should stem from actual and (if possible) real time spending data (e.g. publicspending.gr [7]).

B. Tenders

1) Open Data

The state of data openness in the field of tenders is more evolved than in the case of budgets. This is due to the fact that the nature of the field calls for the design and creation of interoperable platforms, as well as business software that can make use of such platforms in a way that interested parties are automatically updated and notified, in order for fast, timely and up-to-date reactions. Prominent examples of e-procurement portals are the following:

- ted.europa.eu: the official portal of the EU. Member states are legally bound to post calls for tenders for contracts with amounts larger than £100K [10].
- dgmarket.com: online marketplace and e-procurement portal that publishes government notices from countries worldwide.
- fbo.gov: the official portal of the US government. Opportunities over $25K are posted.

In the case of public procurement notices, and given the dynamic and strictly business nature of tenders, this field can give rise to mature and more informed government-to-business transactions, therefore not only using existing open data to assist the pre-award assessment period, but also to update and enrich existing open data on governments and businesses in accordance with past transactions. There are many e-procurement portals in existence that allow their members to post contracts or bid for existing tenders. Even though most of these sites publish notices that contain descriptive metadata, most of these sites do not include APIs that provide machine-understandable formats, but mainly focus on HTML and RSS. Also, even though there exist ontologies and schemata to describe products and services, there is no commonly accepted schema for the universal description of tenders, thus making it difficult to align product and service categories (e.g. CPV vs. NAICS). Given, though, that there is a lot of room for innovation in this field, there have been several approaches of gathering and semantifying such data in order to promote better-automated assessment as well as interoperability between remote and heterogeneous resources. For instance LOTED (Linked Open Tenders Electronic Daily) [11] focused on RDF-izing the RSS feeds that come from *ted.europa.eu* and linked them to the LOD cloud via DBpedia and Geonames. Data provision was done via a SPARQL endpoint, making it a fully semantic web service. The MOLDEAS project [12] aims at aggregating procurement portals such as *ted.europa.eu* and several national tender portals under a common semantic platform and providing a set of tools in order to link notices together (e.g. based on their classification). MOLDEAS provides a fundamental frame of aligning different product classification schemata (such as NAICS and CPV), in order to ensure that intelligent search is performed along all tender sources, despite the initial heterogeneity, thus making the whole approach semantic web-friendly.

2) Ontological Components of the Tenders sub-domain

The Public Contracts Ontology (PCO), introduced by the LOD2 project [13], provides an ontological basis for representing key concepts in tenders. In the PCO, the whole domain is described using existing ontologies as well as novel concepts, such as the classes *pco:Contract* and *pco:AwardCriterion* (where pco is the namespace prefix of the PCO ontology). Existing ontologies include the Payments Ontology [14] to link payments with contracts, the GoodRelations ontology [15] to describe products/services and their metadata, the Dublin Core element set [16] to describe non-functional metadata, and the FOAF vocabulary [17] to describe people and agents in general. These are used in order to be able to represent and link the domain of public contracts with external data. In our case, parts of the PCO are used in order to represent contracts during the tendering phase.

C. Spending

1) Open Data

Government spending is a "natural" field for applied open data, in the sense that it contains a lot of raw data which, on the one hand is of interest to any member of the public that supports transparency in public transactions, and on the other hand provides a solid test bed for researchers to perform data analysis and to provide digested conclusions ready for consumption by the public. As public sector expenditure is a sensitive issue that usually concerns all citizens, there is an increasing effort to release spending data in easily processable formats, by local or central governments throughout the world. Furthermore, the generic information about public expenditure can initiate a vast range of analysis from mathematical networks to data journalism. These include data visualizations, economic and statistical analysis and policy assessment. Concerning the availability of such data, the main difference between existing approaches is that most authorities release large bits of static datasets that contain spending data with regard to a particular period of time, whilst there is a minority of authorities that release spending data in a dynamic way, which in turn is made available on demand, usually through APIs and data endpoints. Worth mentioning in the latter case is the Greek government's Diavgeia project, which ensures by law that every government decision (including spending

decisions) has to be posted in the Diavgeia portal *a priori* to its execution (ex-ante). Public authorities registered to the programme post their decisions, thus forming a continuous stream of dynamic data. Furthermore, an open data API is provided that can be queried on demand and results are returned in XML and JSON formats. Publicspending.gr (PSGR) [7] is a project that processes these data streams, assigning semantics and linking them to the LOD cloud. For this reason, the PSGR Ontology has been introduced. The PSGR Ontology was developed from scratch by re-using some elements from the corresponding Payments Ontology of the British "Opening up government" project (data.gov.uk) and established vocabularies. The corresponding LOD application (publispending.gr) is daily updated and provides various visualizations, as well as a SPARQL endpoint for querying Greek spending data on demand. A thorough review of resources and information about public spending all over the world can be found in *openspending.org*. Overall, it can be said that the state of data openness in the case of spending is better than in the case of budgets, but considerably worse than tenders, which can be attributed to the formality ensued by the business nature of tenders.

2) Ontological Components of the Spending sub-domain

As mentioned earlier, Payments Ontology is a widely accepted ontology for the domain of public spending. In the context of Payments Ontology, the PublicSpending.gr ontology represents public expenditure in a similar way, facilitating their integration. Furthermore, PSGR provides properties for linking payment instances with the Common Procurement Vocabulary (CPV), and is extended by the MOLDEAS [12] project's representation of the most widely used product classification schemas (and the relations between them). Therefore, these ontologies are proposed for the description of the spending domain within the economic LOD.

D. Business Information

As has been discussed, tenders can in part be screened and pre-evaluated by merely using the information that describes a company. For instance, if a particular call for tenders is addressed to businesses with a specific CPA code (or an instance of any other activity classification schema), then a large number of "junk" tenders can be sorted out before proceeding with the evaluation process. The existence of up-to-date company repositories makes the automation of this task fairly trivial, and the release of such information in a linked data manner ensures that different resources that use different classifications can be aligned. Data on corporate entities is stored in business registries that are curated by various official authorities. Depending on the place of origin and the type of business, a registry can hold data about businesses of a particular field, country or region. However, the lack of aggregate registries, as well as the lack of company data availability makes these registries self-consuming and hardly exploitable for other purposes. Nevertheless, there have been efforts at creating centralized databases of companies worldwide. For instance, *opencorporates.com* is a well-recognised effort of aggregating company information from different countries and jurisdictions, and releasing it in open data formats. The opencorporates.com team is working on creating linked data representations out of their databases, by mapping company metadata to certified ontologies such as the Core Business Vocabulary [18] and linking them to other linked data "epicentres", such as DBpedia.org and Geonames. Financial statements and accounting reports that are published by companies contain important data. In a fully digital and open world, financial statements can be used in conjunction with the previously mentioned levels of information (budgetary data, tender history, company descriptions etc.) in order to synthesize informative company profiles that are up-to-date and easy to retrieve and process. Technological standards such as the eXtensible Business Reporting Language (XBRL) [19] are used so that companies are able to produce and store accounting reports in machine-understandable ways that are easy to process and communicate between different parties. By using a standard language such as XBRL, integration of financial data with the semantic web under the linked data paradigm is possible, therefore enriching the economic LOD with important information concerning corporate entities, that would otherwise be costly in time and effort. Ideally, data openness and the creation of linked representations of business information are drivers of dynamic business profiling, which in turn can help set the foundations for improved platforms of business knowledge exchange within the semantic web.

E. Ontology Links between sub-domains

As has been described, each component in the cycle of Figure 1 defines its own sub-domain and is generally represented by an ontology, or a set of ontologies, as was described briefly in each section. Wherever possible, existing ontologies are designed to ensure the maximum degree of interoperability between remote resources and the economic LOD domain. This can be seen in Table 2. However, linking the different sub-domains is not always possible using existing ontologies, therefore new concepts need to be defined, thus creating a super-ontology that can be derived by the ontology links.

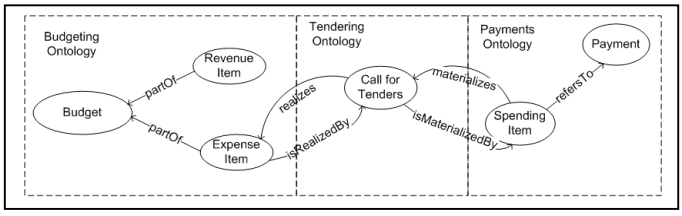

Figure 2: Lifecycle of economic LOD components

Briefly, the following points are made regarding the links between the different sub-domains:

(1) Budgets to Tenders: properties are needed to link budget concepts (such as Expense Items) to tenders. This is achieved with a property that describes this "realization" of a published expense item to an official call for tenders.

(2) Tenders to Spending: when a contract related to a particular call for tenders is approved and assigned, it is usually

followed by an official decision, or a similar document. This is considered as a Spending Item, which in turn is associated with a particular payment instance. This payment instance, in turn, describes the information associated with the expenditure. For linking tenders with spending items, ontological properties are needed to describe this flow of information.

Sub-domain	Ontology/Ontologies
Budget	Novel ontology. Some reuse from [9]
Tenders	Public Contracts Ontology New elements in context-specific cases
Spending	UKPayments & Publicspending.gr Ontol.
Business Registries	Core Business Vocabulary
Financial Statements	XBRL taxonomy
Agents	FOAF, Vcard
Activity Classifications Product Descriptions	MOLDEAS ontology and mappings Good Relations ontology

Table 2:Subdomains and corresponding ontologies of the LOD economy

V. To the future

Enabling the semantic processing of open data about public budgeting and spending, e-procurement and business information would substantially improve transparency and efficiency in the economic domain. This paper frames the cyclical flows and the engineering of economic LOD related to public budgeting and spending. The provision of linked open execution reports of the public budget enables a thorough, easy and updated online access to who, when, why and what a public institution spends. Beyond transparency, economic LOD provides an extra tool to the governments for implementing advanced budget monitoring processes and multiple and more complex criteria for eligibility in e-procurement with minimum costs. In the business side, economic LOD can be dynamically integrated in business information systems for stimulating dynamic resource allocation with lower cost and wider application range. This type of integration will benefit more the SMEs, since they lack advanced business intelligent systems and sufficient R&D budgets. Efficiency for business could be upgraded in the case where reporting information is augmented to include electronic invoicing through the web. We are still away from fully implementing the proposed model of economic transactions. In the domains of public tenders, contracts and spending have been initiated important efforts to build separate ontologies that support the semantic processing of the underlying economic data. In the field of budgeting, the efforts are not having the same direction. This may happens because scholars of public economics are not familiar with the web ecosystem. Web scholars have the potential to help budget experts to create machine-understandable global standards for forming public budgets. The next step of this ongoing research is to provide proof-of-concept implementation of the proposed model by involving domain experts from public budgeting and business intelligence communities.

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