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Dynamics of global remittances: A graph-based analysis☆

Felipe Lillo*, Leidy García, Valentín Santander

Department of Economics and Management, Universidad Católica del Maule, 3605 Avenida San Miguel, Talca, Chile

HIGHLIGHTS

- Interactions of global remittances are studied by applying a graph modeling approach.
- Potential uses of the approach are related to economic policy development.
- Results evidence some traces of a power law in degree distribution.
- Cycles are presented as useful tools for detecting circular flows of money.

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ABSTRACT

Human migration is an increasing world-wide phenomenon by which people leave their homeland to find better living conditions. This phenomenon entails financial issues for host countries. One of these issues are remittances. Remittances produce money flows that can considerably interfere with country micro and macroeconomics. Therefore, the understanding of remittance functioning at global scale is crucial for adopting adequate control policies in areas such as tax evasion, capital flow and money laundering. This work contributes to such understanding by both developing and analyzing a graph modeling approach that describes the interaction, concentration and circular patterns of world-wide remittances. The graph model analyzes degree distribution, vertex degrees and two-vertex cycles and it is constructed from World Bank data. As a result, the remittance graph evidences a power law in the degree distribution, very concentrated producer and receiver remittance communities and large circular flows of remittances.

1. Introduction

Human migration is an important social phenomenon. Countries and people are affected by this phenomenon in different ways. From a financial view, an aspect linked to migration is the flow of money between immigrants and their relatives. Such money flow is also known as remittances.

The role of remittances in the economy and financial development of nations has been seriously researched. Evidence is found supporting the contribution of remittances to poverty reduction and human capital increase (Cuecuecha and Adams, 2016). Additionally, remittances have proven to be useful in the prediction of investment patterns, consumption and gross domestic product (Ahmad and French, 2014). Remittances also mitigate impacts from economic recessions (Chami et al., 2012), and collaborate through taxation by incrementing government income (Abdih et al., 2012).

Despite economic and financial importance, the dynamics of global remittance flows have been incipiently investigated (Ambrosius and Cuecuecha, 2016; Bouoiyour and Miftah, 2015; Brown and Jimenez-Soto, 2014). The answers to questions such as, "How do remittances function in a global network?", "Is there any collective behavior associated to either senders or receivers?" and "There exists circulars remittance patterns between senders and receivers?" have been partially addressed by the literature and pose economic and financial challenges that might influence the development of policies towards migrants. This work seeks to contribute to the study of remittance flows and their effect on policy decisions by introducing a graph modeling technique capable of describing interaction, concentration and circular patterns of global remittances. A benefit of a graph as a modeling tool is its explicitness and simplicity. A graph is able to deliver straightforward representation of a remittance interaction processes without resorting to a high level of abstraction. All information can be easily displayed by simply employing vertices and edges. Additionally, graphs are considered as helpful tools for "mining" large datasets. Cook and Holder (2006) informally describe the relation between

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* Corresponding author.
E-mail addresses: flillo@ucm.cl (F. Lillo), legarcia@ucm.cl (L. García), vsantand@ucm.cl (V. Santander).

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graphs and data mining as "the process of extracting relational knowledge between independent entities and their attributes".

The remainder of the paper is organized as follows. Section 2 reviews literature related to graph models in the study of migration and remittances. Section 3 describes the graph model approach to analyze of global remittances. This section also characterizes main topological measures and graph substructures of the approach, emphasizing their interpretation in the context of remittance flows. An empirical analysis is introduced in Section 4. Remittance data provided by the World Bank is used for testing the model. Moreover, some theoretical results regarding the probabilistic behavior of the graph model are also presented. Finally, Section 5 provides conclusions and future research.

2. Graph models for migration and remittances

Graphs are direct tools that can represent migration dynamics between global countries. Nodes and edges are used for modeling migrant interactions between two countries so that the obtained graph can be fully characterized by several topological measures such as clustering coefficients, degree distribution, density and such. A work addressing the use of graphs for the representation of human migration interactions is Davis et al. (2013), where the author introduces a complex network model to determine global migration patterns. Specifically, the estimation of degree distribution, clustering coefficients, network transitivity and average path length are described for a network built from several bilateral migration matrices. These matrices include migrant stock information from 226 countries between the years 1960 and 2000. The authors conclude that the global human migration network features a strong small-world phenomenon as well as groups of countries that form migration communities based largely on historical, cultural and economic factors. Similarly, Fagiolo and Mastrorillo (2013) study the topology of a bilateral migration network based on migration data over the same period of 1960 to 2000. Once again, degree distribution, clustering coefficients and other similar network metrics are computed. Main results suggest that socioeconomic, geographic, and political factors are the most important in shaping the structure of the international migration network than local-network properties. Migration flows are investigated in Porat and Penguigui (2014) by constructing a directed graph from bilateral migration information. Unlike previous studies, a migrant flow is defined as the difference of the migrant stock between two countries. Hence, the countries are considered to be connected if the corresponding difference is greater than a specified value. This method generates a particular network whose degree distribution is analyzed. The contribution of the paper is a characterization of both immigration and emigration according to the degree level of each country. Immigration depicts an uneven degree distribution so that a classification in low, high and massive degrees of immigration is possible. On the other hand, emigration follows a homogeneous degree distribution at global level.

Relationships between human migration and global trade are also analyzed by models based on graphs. Fagiolo and Mastrorillo (2014) collect global data of human migration and bilateral trade over a forty year period (form 1960 to 2000). The global migration graph (network) is generated by linking countries with weighted edges that represent levels of migrant stock. Likewise, global trade networks are constructed by considering export or import flow as weight. The resulting networks are topologically studied arriving at the following conclusions: (1) there is a strong correlation between migration and trade networks; and (2) centrality of the migration network stimulates bilateral trade at any network level. Recently, Sgrignoli et al. (2015) published a similar manuscript where the interaction between migration networks and trade networks was researched. The methods and conclusion share similarities with the previous study. However, the use of a specific set of trading products, as well as the application of a condition to identify links where trade surpasses average values constitutes an important contribution from a modeling viewpoint.

Remittances behavior is another important aspect associated with human migration. Remittances are funds transferred by a person residing in another region to a person in the region of the remittee's region of origin (family member or friend) without being directly compensated by a counterstream of goods or services, Schrieder and Knerr (2000). Readers can refer to Brown and Jimenez-Soto (2014) where a complete review and analysis related to migration and remittances is provided. This work describes three main guidelines employed for the development of remittance models: (1) The determinants of remittances. This guideline seeks both to identify those factors influencing the decision of remitting and to discover interdependencies among such factors. (2) The impact of remittances on household microeconomics such as income, poverty, resource allocation, etc. (3) Effects of remittances at macroeconomic level such as economic growth and financial development.

From a modeling perspective, predominant approaches for modeling dynamics and dependencies of remittances are based on econometric techniques. This empirical approach uses a regression model as main tool. Special attention is given to both the Tobit and Probit models which are commonly used by studies related to remittances. Complete descriptions of these models are found in Tobin (1958) and Bliss (1934). Tobit models, also called censored regression models, are intended for the establishment of linear relationships between variables that are affected by either left or right censoring. Similarly, the Probit model is a type of regression, but the dependent variable only takes binary values (binary classifier). Once it is applied, the model determines whether or not an observation fits in a specific category. Examples of recent research that takes advantage of an econometric approach for the study of remittances (particularly related to Probit and Tobit models) are: Ambrosius and Cuecuecha (2016), Bouoiyour and Miftah (2015), Amuedo-Dorantes and Pozo (2014), Ecer and Tompkins (2013) and Bettin et al. (2012). Literature also evidences applications of modeling techniques based on both simulation and Bayesian networks. García-Alonso et al. (2012) construct a remittance assessment model based on a Monte-Carlo simulation and fuzzy logic to predict the behavior of remittances in North–South economies. This model is also supported by a Bayesian network which establishes the dependence relationships between socio-economic variables under uncertainty conditions. García-Alonso et al. (2013) have recently enhanced this model by including a multi-objective evolutionary algorithm. Such an algorithm permits the assessment of dependencies in the Bayesian network to be computed automatically.

In conclusion, a scarce usage of graph modeling approach for analysis of remittances is noticed throughout the literature. This paper contributes to the same line by developing a graph approach for the study of remittance behavior. In a practical context, such an approach is a useful tool for policy makers since a graph provides a descriptive "picture" of the migration situation at a given time.

3. Model description

3.1. Graph model based on remittances

Directed graphs are used for representing remittance interactions between country pairs. A directed graph $\mathbf{G} = (V, E)$ is a structure that comprises a finite set V of elements called vertices and a set E of ordered pairs of vertices called edges. For this work, the set V is conformed by countries, whereas the set E is composed