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A macro-economic model to forecast remittances based on Monte-Carlo simulation and artificial intelligence

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ABSTRACT

A computer system based on Monte-Carlo simulation and fuzzy logic has been designed, developed and tested to: (i) identify covariates that influence remittances received in a specific country and (ii) explain their behavior throughout the time span involved. The resulting remittance model was designed theoretically, identifying the variables which determined remittances and their dependence relationships, and then developed into a computer cluster. This model aims to be global and is useful for assessing the long term evolution of remittances in scenarios where a rich country is the host (United States of America) while a poor country is the where the migrant is from (El Salvador). By changing the socio-economic characteristics of the countries involved, experts can analyze new socio-economic frameworks to obtain useful conclusions for decision-making processes involving development and sustainability.

1. Introduction

Monte-Carlo simulation has been widely used to model complex systems in economy. These models let researchers evaluate the evolution of socio-economic variables, like remittances, in uncertain environments (Kydlandl, 2006; Stern, 1997). Input variables in Monte-Carlo are random variables whose behavior depends on their corresponding statistical distributions (Fishman, 1996; García-Alonso & Pérez-Alcalá, 2008). When there are not enough raw data, the expert-based selection of these statistical distributions (StD) is critical to determine the expected outputs (Kuhl, Lada, Steiger, Wagner, & Wilson, 2008).

Monte-Carlo simulation models are completely blind. This means that it is very complicated to make them understand complex dependence relationships (DR) among covariates. Bayesian network models (Barreiros & Vargas, 1998) are appropriate methodological approaches for understanding causal-based DR when they exist. When these DR are algebra-based, they can easily be included in a simulation engine (Fishman, 1996). However, when they are expert-based (causal rules) – experts agree that they exist but it is very difficult to make them explicit because the absence of data or its bad quality, only artificial intelligence models can be used to incorporate them into a simulation engine (García-Alonso, 2008; Liu, Yue, Su, & Yao, 2009).

A fuzzy inference engine was designed to evaluate expert-based DR (García-Alonso, 2008; Gegov, 2007). This engine designs appropriate fuzzy rules automatically once the input values have been determined by the simulation engine according to expert-based prerequisites (Cox, 2005; Fishman, 1996; Stern, 1997). These rules determine the values of the analyzed variable – the output of the fuzzy inference engine – (García-Alonso, 2008) that produce a stochastic distribution because: (i) the input variables are stochastic and (ii) the interaction among input variables produces random effects.

The aim of this paper is to design and develop a remittance assessment model based on Monte-Carlo simulation and fuzzy logic to forecast the evolution of this variable throughout time comparing specific North–South economies. This model evaluates the relationships between socio-economic variables in uncertainty conditions modeled in a Bayesian network. The resulting model has been checked by considering United States of America (USA)–El Salvador remittance flows.

Remittances, mainly in poor countries, are one of the critical elements for economic development. They have been defined as the current transfers made by migrants who live and are employed in other economies. From a simplified point of view, migrants are those workers who move to an economy different from their origins and remain there, or are expected to stay a year or longer (Amuedo-Dorantes & Mazzolari, 2010; International Monetary Fund – IMF, 2008). In 2008 officially recorded remittances at international level were formally estimated at $397,047 million per year, and have undergone a great increase in recent years from

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the $2049 million per year in 1970 (World Bank, 2010). Remittances are of increasing scientific interest because they are much more stable over time than private capital flows and exports, which makes them a very attractive source of foreign financing for poor countries (Wu & Zeng, 2010). In addition, remittances are unrequited transfers of capital that, unlike other capital flow, do not create future obligations (Chami et al., 2008). In poor countries, the total amount of remittances is greater than the amount of direct foreign investment, portfolio flows from financial markets and official development assistance (Amuedo-Dorantes & Mazzolari, 2010). These facts suggest that the macroeconomic effects of remittances have relevant implications for policy makers in these countries (Chami et al., 2008).

Borjas (2008) considered that wages abroad depend on a socio-economic vector that describes the structure of the host countries, the number of years that migrant workers live in the host country, the age of workers in the year analyzed and, finally, when they arrived in the host country. His microeconomic model of individual choice established that people decide to migrate depending on a cost-benefit relationship that involves (Borjas, 2008; Todaro, 1989) the differential of wages between the country of origin and the host country (Gandolfo, 1998), the unemployment differential and, finally, the initial investment needed, including transport costs, language, religion, culture, nationality requisites, etc. A potential migrant decides then to migrate if, according to his skills, he expects to obtain a measurable profit.

The New Economy of Migration (Massey et al., 1998) also includes host country benefits as another variable to estimate the number of migrants. The existence of social networks in the host country is also highlighted in the Social Capital Theory (Massey & Emilio, 1994) while the Segmented Labor Market Theory (Piore, 1979) explains international migration as an answer to the permanent demand for immigrant labor that is inherent to the economic structure of developed nations.

The propensity of the migrant population to remit wages back home is the third variable to explain remittances. According to Adams (2008), this variable is a function of the migrant's profile and skills, the number of years living in the host country and the income of the family at home. The differential of interest rates was included by Chami et al. (2008) as another relevant variable. Higgins, Hysenbegasi, and Pozo (2004) and Freund and Spatafora (2008) include transmission costs, exchange rates and the social stability of the country of origin in their analysis of migrant propensity to remit wages back home. Finally, Lueth and Ruiz-Arranz (2006) also suggest that higher inflation in the home country increases remittance flows to compensate the loss of purchasing power.

This paper is structured as follows: first, the North–South Remittance model is developed theoretically and then the dependence relationship modeling is described. In section three the resulting model is applied to the situation involving the USA and El Salvador. Some relevant results are then described in section four and, finally, a brief discussion of relevant issues concludes this paper.

2. The Bayesian network: modeling remittances

The North–South Remittance Model (NSRM) includes three main variables considered outlets in a Bayesian network (Fig. 1(a)): wages received from abroad (Wx_t), the migrant population (Nem_t) and the propensity to remit wages (Rw_t), being t the time.

Remittances (1) have been defined as transfers made by migrants who are employed and have lived (at least one year) in other economies (IMF (International Monetary Fund), 2008).

$$Tre_t = \sum_{i=1,k=1}^{3,2} Rw_{ikt} Wx_{ikt} Nem_{ikt} \quad (1)$$

Tre_t being the remittances received in the home country in year t according to specific migrant skills i ($i = 1$) low-skilled – less than 8 years of schooling, $i = 2$ medium-skilled – 9–12 years of schooling – and $i = 3$ highly-skilled – 13 years or over of schooling.

Docquier and Marfouk (2005) and the ways of sending the remittances k ($k = 1$ formal and $k = 2$ informal). Rw_{ikt} is the corresponding propensity to remit wages, Wx_{ikt} are the wages earned abroad and, finally, Nem_{ikt} is the migrant population in each collective.

Wages abroad Wx_{ikt} are the average monetary units earned by each migrant collective in the host country (2); this variable defines the first dependence relationship (DR) in the model because the algebraic structure of the function (Borjas, 2008) is not yet defined:

$$Wx_{ikt} = f(Sec_{ikt}, Yr_{ikt}, Em_{ikt}) \quad (2)$$

being Sec_{ikt} the socio-economic characteristics of the environment in t. This variable summarizes the average labor market framework and has been defined in a [0,100] range where 0 means very poor labor market conditions and 100 means very favorable conditions. Yr_{ikt} is the average number of years that the migrant collective remains in the host country. Finally, the employability Em_{ikt} includes all the characteristics of the migrant collective on average – skills, schooling, labor experience, language proficiency, etc. This variable is also defined within a [0,100] range where 0 means possessing very poor skills and 100 means very highly skilled.

Migrant population Nem_{ikt} (3) is the number of people in each collective who have migrated and stayed in the host country in the year t:

$$Nem_{ikt} = Mp_{ikt} \times Nt_{ikt} \quad (3)$$

where Mp_{ikt} is the propensity to migrate (percentage) and Nt_{ikt} the population of the collective in the home country in t. The NSRM defines Mp_{ikt} (4) as another DR:

$$Mp_{ikt} = f(Wd_{ikt}, Wu_{ikt}, In_{ikt}, Hsb_{ikt}, Es_{ikt}) \quad (4)$$

Wd_{ikt} being the differential (times) wages on average (Borjas, 2008; Todaro, 1989) in t, Wu_{ikt} the average differential (times) unemployment rates (Todaro, 1989), In_{ikt} the average initial investment – within a [0,100] range (0 means no investment needed and 100 means financially impossible), Hsb_{ikt}, the host country social benefits (differential) on average compared to those in the home country and, finally, Es_{ikt} shows the difference (scale) in potential economic growth between the two countries.

The last input in (1) is the propensity to remit wages Rw_{ikt} (5), which is another DR:

$$Rw_{ikt} = f(Sk_{ikt}, Ag_{ikt}, Hmf_{ikt}, Hsf_{ikt}, Id_{ikt}, Tc_{ikt}, Sst_{ikt}, Md_{ikt}, Ppp_{ikt}) \quad (5)$$

being Sk_{ikt} the average migrant skills (scale) in t. This variable includes years of schooling, academic level, migrants' experience and the labor orientation of workers. In addition to this variable (5) also includes: Ag_{ikt} which is the average migrant age; Hmf_{ikt} which describes the average family structure (scale) in the home country; Hsf_{ikt} the average family (scale) in the host country; and Id_{ikt} the average nominal interest rate differential (times).

Other variables included in (5) are: Tc_{ikt} transaction costs (scale) on average – the cost of sending money; Sst_{ikt} the average socio-political stability (scale) of the home country; Md_{ikt} the average duration (Dustmann & Mestres, 2010) of the migration (years) and Ppp_{ikt} the average purchasing power parity (times) – the relation between the price differential and the exchange rate differential.

This structure (Fig. 1(a)) defines a standard Bayesian network (Directed Acyclic Graph) that varies throughout the time span (Fig. 1(b)):