University of Economics in Katowice

Journal of Economics and Management

ISSN 1732-1948 Vol. 20 (2) • 2015

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# Money as a network good[1]

## Abstract

Many economic phenomena, including flows of money, can be treated as manifestations of operation of specific networks. In contrast to the popularity of analyses of network structure and dynamics in sociology and physics, economic investigations concerning network approach in general and network properties of money in particular have not been popular until recently. This paper presents the concept of money as a network good and its features (complementarity, standardization, consumption externalities, switching costs, lock-in, dependence on social preferences and expectations and economies of scale in production). It is asserted that network theory of money may shed new light on such processes as monetary integration.

**Keywords**: money, network effects, network structure, monetary integration.
**JEL Classification:** E40, D85, F36.

## Introduction

The vast majority of economic phenomena can be interpreted in terms of dynamic processes occurring within a specific network. Taking into account that without interactions between economic agents, there would be no complexity, one can state that without networks, economies would not be complex adaptive systems (Beinhocker 2006, p. 141).

Undoubtedly, one of the most important networks in the modern globalized economy is constituted by flows of money. Nevertheless, money has been relatively rarely analyzed as an example of a network good, as most of the publica-

[1] This research project was funded by the National Science Centre (decision number DEC--2013/09/D/HS4/01157).

tions discussing network externalities occurring within economic systems usually refer to privately supplied products on more or less competitive markets (see e.g. Farrell, Saloner 1985; Katz, Shapiro 1992; Katz, Shapiro 1994), while money may be supplied publicly and/or privately and its market tends to be monopolized.

The concept of money as a network good may help to overcome some problems associated with defining money in terms of the physical material from which it is made, as well as provide an alternative to the functional definition of money. Network properties of money can be linked with its function of medium of communication which to some extent may be perceived as superior to other functions because it integrates both economic and social aspects of circulation of money (Włodarczyk 2010, p. 51).

A network approach towards money allows for a new interpretation of phenomena on which traditional theories of money are often criticized, namely the origin of money and its evolution, competition and choice between different monetary standards (with an important role of social preferences and self-fulfilling expectations), as well as the process of monetary integration (Stenkula 2008, pp. 6-7). In general, it seems that the reason for economists not to analyze network structure and dynamics in detail has been the incompatibility of the network theory with the equilibrium paradigm (Beinhocker, 2006, p. 141).

In order to design an appropriate methodological approach towards a research on network properties of money one should notice that on one hand, modern monetary network could not exist without information and communication technologies (ICT), but on the other hand, its essence consists in social interactions. Therefore, the concept of money as a network good can be investigated from different point of views, from sociological to formal analyses of monetary network's structure and function. Integration of various approaches may result in further development of the network theory of money.

The aim of this paper is to describe characteristics of money perceived as a network good, summarize empirical investigations on the structure of monetary networks and discuss some links between monetary integration and network externalities. This paper presents results of preliminary research in this field, therefore it is based mostly on critical analysis of topical publications.

## 1. Characteristics of network goods

Network goods (e.g. telephones, fax machines, computer software, CD players, ATMs, banking services) are characterized by following features (Shy 2001, pp. 1-6; Januszewski 2013, pp. 30-34):

- complementarity – network goods are not used or consumed independently of other goods;
- standardization – network goods must operate on the same standard or be compatible with other standards (however, apart from social benefits from standardization, there arise also important social costs such as reduction of variety and retardation of innovation, especially under incomplete information; cf. Farrell, Saloner 1985);
- consumption externalities – utility of a network good depends positively not only on the number of its users (which is associated with direct network effects), but also on the variety of their complementary goods which also influences the number of its users (indirect network effects); offering users an access to a larger network is equivalent to offering them a better product (however, a rapid increase in the number of users may lead to congestion or other problems with infrastructure that result in decreased consumer's utility – negative network effects);
- switching costs – costs borne by users who decide to change the standard (e.g. compensation for breaking a contract, costs of learning and training, costs of converting the data, costs of search, loss of benefits related with loyalty programs, etc.);
- lock-in – a situation when a user of a network good does not switch to another standard (presumably a better one) due to high switching costs (*excess inertia* means that no user from a large and already established network wants to be the first to use a new network);
- important role of preferences and consumer's expectations influencing the life cycle of a network good;
- significant economies of scale in production – costs of production of the first unit of a network good are very high, whereas marginal costs may be treated as negligible which implies that markets for network goods are not perfectly competitive (in fact they are usually dominated by one company and vulnerable to market failures).

The reason why the perfectly competitive equilibrium in a market for network goods is not efficient lies in the fact that because of adoption externalities (social marginal benefits of one more user joining the network exceed private marginal benefits) the equilibrium network size is smaller than the socially optimal one. Even small adoption externalities may lead to large social welfare losses (Katz, Shapiro 1994, p. 96).

Investment in expanding the network is possible, but requires property rights. However, markets for network goods in which new technologies are proprietary usually exhibit *insufficient friction* (a bias towards new technologies as opposed to excess inertia which is a bias against new technologies). If this is the case, a new standard may dominate the market even when it does not contribute to social welfare (Katz, Shapiro 1992, p. 73).

On the whole, despite market imperfections, government intervention in standard setting may be undesirable or even harmful because policymakers may be influenced by companies lobbying for imposition of Pareto inferior standards (Shy 2001, p. 6). Furthermore, welfare considerations seem to be particularly important in case of network goods, because due to the existence of multiple fulfilled-expectations equilibria fundamental theorems of welfare economics may not apply to markets for network goods (Katz, Shapiro 1994, p. 94).

## 2. Money as an example of a network good

Money exhibits all the features of a network good mentioned in the previous section, namely:

- complementarity – use of money is directly linked with the consumption of almost every good (this feature corresponds to the function of money as a medium of exchange);
- standardization – without standards no accounting system could exist, making it virtually impossible to conduct economic activity on a larger scale (this feature is closely linked with another function of money being a unit of account);
- consumption externalities – use of a currency by a large number of users may imply lower transaction costs (e.g. lower spreads, lower interest rates), however, negative network effects may also arise (e.g. a high demand for CHF-denominated loans, due to their relatively low interest rates, was one of the factors that led to the increase of demand for CHF, appreciation of this currency, higher overall costs of CHF-denominated loans and an unprecedented intervention of Swiss National Bank in 2011);
- switching costs – costs borne due to a change of the standard may depend on the scale of the whole operation, whether it is an individual company starting to use a different currency for invoicing and settlement purposes, or a whole economy joins a single currency area (in the latter case, apart from costs of learning and training or costs of converting the data, one should also take into account costs of a nation-wide informational campaign, costs of monitoring the prices after adoption of a new currency, loss of benefits related with an autonomous monetary policy, etc.);
- lock-in – a situation when an individual agent or the whole economy does not switch to a better standard because of high switching costs (due to the fact

that money as a network good does not require costly infrastructure, financial costs may not play as important role as other costs, e.g. loss of reputation if a company breaks a long-term contract or loss of credibility if a country no longer fulfills its political commitments);
- important role of social preferences and expectations influencing the life cycle of a network good (e.g. social opposition may diminish potential benefits of changing the standard, with limitation of cognitive capacities of economic agents being one of the reasons of favoring an incumbent money, cf. Luther 2013, pp. 128-129);
- significant economies of scale in production – costs of production of the first unit of money are very high, while marginal costs tend to be the lower, the more dematerialized money is (the marginal cost of production of a coin is greater than of the banknote, not to mention electronic money).

In general, people tend to be willing to receive money, because other agents (including the government) are also willing to accept money (Shy 2001, p. 201). This universal consent on certain means of payment seems to be the most important source of network effects regarding money. In the case of money, direct network effects mean that utility of a currency increases with the number of its users (which is one of the arguments in favor of monetary integration), while indirect network effects are more complex than in the case of other network goods, because they can be associated both with liquidity of money (its exchangeability for goods) and convertibility of currencies for other currencies.

The observation that even if each realized transaction involves only two parties, the use of money means that they refer their offers to all potential actions of other members of the society (which in fact depicts direct and indirect network effects that can be attributed to monetary transactions), has been discussed for a long time by sociologists (see e.g. Simmel 2004; Weber 1978; Dodd 1994).

Nonetheless, within the field of economics it is difficult to indicate precisely the beginning of the network theory of money. Although historical investigations are outside the scope of this article, it is worth noticing that many authors refer to C. Menger's articles or even earlier publications. For instance, already W.S. Jevons noted that in general people possess no deep knowledge on the nature of money and the only important thing for them is whether the coin they receive will be accepted by others (Jevons 1919, p. 78).

According to Menger, the more people demand a specific good or asset (for consumption or transaction purposes), the more marketable it will be, and therefore the higher utility it will have as a means of payment. Money has to be the most marketable good or asset in order to become the generally accepted medium of exchange (Menger 1892; Stenkula 2003, p. 593). Thus, liquidity of money (contemporary equivalent of marketability) can be related with indirect network effects.

An interesting interpretation of money as a social institution that emerges from interactions between leaders and masses was provided by F. von Wieser. Existence of leaders and followers can be perceived as a result of unequal distribution of knowledge about market processes among economic agents: better-informed agents discover earlier the advantages of indirect exchange and their behavior is subsequently imitated by followers. The next phase of the process of emergence of money (convergence to a monetary exchange economy) requires selection and standardization so that eventually one good or asset becomes money. There arise positive and negative feedbacks in this self-organization process that may include path-dependency or hysteresis effects and lead to multiple equilibria (Festré, Garrouste 2008, p. 15-16).

Taking into account that money reduces transaction costs and facilitates computations associated with trade, one can come to a conclusion that introduction of fiat money into an economy leads to a Pareto-optimal allocation. However, it is enough that a relatively small number of individuals refuses to trade with money to distort the whole process which confirms the role of social perception of the value of money. Therefore, in order to reduce the risk of a monetary crisis governments may give their currency a status of a legal tender. In such a case, even if money cannot be used for exchange purposes (due to the lack of universal acceptance within the society), at least it can be used to pay taxes (Shy 2001, pp. 203-204).

Apart from the number of users (the size of the network), also their location from the point of view of a particular user is important – it is enough when his trading partners accept the same medium of exchange (not all traders) (Luther 2013, p. 128). This observation not only justifies the need for analysis of the structure of monetary networks, but also suggests that this structure may not be uniform.

## 3. Structure of a monetary network

The structure of a monetary network refers to its topology and interactions between its nodes which are usually assumed to represent economic agents, banks, currencies or even whole countries. Theoretically, several network topologies are possible (including a fully connected network, a partially connected network, e.g. hierarchical network, star network, ring network, etc.). Nevertheless, most of these classes can be excluded on the basis of empirical research.

In general, understanding of the structure of complex real world networks such as monetary networks has been made possible mainly due to recent achievements in physics and discovery of significant structural similarities in networks operating in distinct contexts. Most of real world networks exhibit power-law degree distribution (the number of nodes with $k$ or more links is proportional to $k^{-\gamma}$), large clustering coefficients and the so called small-world phenomenon (the average distance between any pair of nodes is very small) (Boss et al. 2004).

If a monetary network is associated with a banking network, a fully connected network (with all banks mutually linked via interbank market and their liabilities), in comparison with a partially connected one, is characterized by a greater liquidity saving (banks may keep smaller reserves when they can take advantage from the interbank market), but also by a greater contagion risk (the interbank markets makes participating banks more fragile) (Rørdam, Bech 2009). In other words, there is a trade-off between stability and efficiency of the network because on the one hand in a complex networks hubs usually provide an efficient access to most of the nodes, but on the other hand, in a scale-free network they are vulnerable to attacks (Inaoka et al. 2004).

For many countries, e.g. Austria (Boss et al. 2004) and Japan (Inaoka et al. 2004), an empirical analysis reveals that from the point of view of the number of transactions and the amount of money transferred banking networks exhibit self-similarity described by a power-law degree distribution, which may be linked to the fact that size and wealth distributions of the banks also exhibit power exponents. Furthermore, people tend to perceive larger banks as more stable ones that are less likely to go bankrupt (Shy 2001, p. 187). However, some analyzes confirm concentration of a banking network, but exclude power-law distributions, e.g. in Denmark (Rørdam, Bech 2009) or in Italy where the banking network is fairly random (Iori et al. 2008).

Also research conducted for the foreign exchange market perceived as a network of currencies mutually linked via exchange rates confirms a scale-free, small-world, and hierarchical structure of this market with possible deviations towards a more random network for a limited number of currencies (e.g. Li et al. 2004; Kwapień et al. 2009). Even very simple calculations linking the rank of a currency with its turnover on foreign exchange market allow to demonstrate a power-law relationship (see Table 1).

**Table 1.** Power-law exponent for foreign exchange turnover by currency (1995-2013), daily averages in April

| **Year** | **1995** | **1998** | **2001** | **2004** | **2007** | **2010** | **2013** |
|---|---|---|---|---|---|---|---|
| Exponent $\gamma$ | 2.439 | 2.302 | 2.648 | 2.604 | 2.491 | 2.309 | 2.228 |
| $R^2$ | 0.890 | 0.910 | 0.910 | 0.890 | 0.870 | 0.880 | 0.840 |

Source: Author's calculations based on BIS (2013).

Taking into account that the structure of monetary networks may not be stable over time, one should put emphasis on analysis of network dynamics and related processes.

For instance, Risau Gusman, Laguna and Iglesias (2005) analyzed both wealth distribution and network dynamics under following assumptions: initially the network is random, interactions are only allowed between connected agents, agents cannot win more than they put at risk (according to their risk aversion), the probability of favoring the poorer agent is $p \geq 0.5$ (to simulate regulation aimed at redistribution), the winner in the exchange not only increases his wealth, but he is also rewarded with a number of links proportional to the amount he won. As a result they found that such a network changes from random one to a network where the richest agents concentrate most of the links. Smaller connectivity of the poorest agents prevents them from losing more money.

Such simulations are consistent with observations that people usually gain at a rate proportional to how much they already have, therefore, in line with a power law, rich get richer which is often referred to as preferential attachment (Newman 2010, p. 488). Moreover, clear preferential attachment effects are visible, even if the reported values do not correspond to the real values (Newman 2010, pp. 509-510) which emphasizes once again the role of social preferences and expectations.

These social aspects make it impossible for a global, uniform financial system to emerge and exist. Contrarily, global financial system comprises a lot of monetary networks that construct their own times and spaces and include different media of exchange and different users of money along with their personal attitudes and beliefs concerning money (Thrift, Leyshon 1999, p. 161).

## 4. Monetary networks and monetary integration

So far, the process of monetary integration has not been investigated in detail through the prism of the network theory despite the fact that such analyses could lead to interesting results. The process of monetary integration cannot be modeled as a spontaneous, evolutionary process associated with the emergence of money as it involves planned action of governments aimed at coordinated fixing of exchange rates and optionally introduction of a common currency.

Nevertheless, the already existing network literature on emergence of money may provide a starting point for further analyses. Firstly, if the nodes in a network are highly connected, a single good or asset is likely emerge as the medium of exchange, however, when network connectivity decreases, more than one medium of exchange can exist simultaneously (Giansante 2007). This observation can be linked with what is emphasized by the theory of optimum currency areas as the need for high degree of economic integration between countries joining a fixed currency area. Secondly, the network structure is important because holding the number of links constant, a scale-free network allows for more exchanges than a random one (Paolucci 2013) and monetary integration is supposed to increase the volume of trade between integrating countries and thus to reduce asymmetric shocks (De Grauwe 2007, p. 27). Thirdly, social aspects of the emergence of money can be depicted with the help of doubly structural network model in which two layers of interpersonal social networks and intrapersonal recognition networks allow to handle with social propagation of agents' knowledge and recognition such as exchangeability or acceptability of goods or assets (Kunigami et al. 2010).

One of the advantage of monetary integration is directly linked with the consumption externalities of a common currency (lower transaction costs and increased efficiency). Besides, in the international monetary system the new currency is likely to weigh more than sum of individual currencies prior to establishing a monetary union (De Grauwe 2007, p. 78).

However, there arise several costs that might be attributed to the network character of money apart from already mentioned contagion risk. For example, as companies introducing new, incompatible standards usually bring out their products earlier than would be socially desirable (Katz, Shapiro 1992, p. 73), the governments may also be tempted to introduce a common currency too early (which may explain the fact that countries not fulfilling Maastricht convergence criteria were allowed to adopt the euro). Furthermore, the distribution of social benefits associated with the growth of the network (e.g. associated with subsequent enlargements of a single currency area) tends to be unequal, favoring the most connected agents and countries, thus increasing inequalities both in the microeconomic and macroeconomic scale.

Obviously, the trade-off between efficiency and stability seem to remain one of the most important problems of monetary integration, but network approach with analysis of monetary network structure and dynamics may shed new light on this issue and also inspire further development of the theory of optimum currency areas which still lacks operational measures of optimality of currency areas.

## Conclusions

This paper discussed the possibility of treating money as a network good, analyzing the structure of monetary network and its relationship with the process of monetary integration. Further research into the network theory of money could investigate not only structure, its dynamics, but also function of monetary networks (e.g. monetary network failure or resilience, systemic risks in monetary networks under monetary integration) with their implications for economic growth and welfare.

Welfare implications seem to be particularly interesting because although money as a network good emerges spontaneously, it may not have the socially most preferable features (Stenkula 2003, p. 595). Due to the existence of multiple equilibria the relationship between money and welfare seems to be problematic. Social processes and institutional arrangements (including government's intervention) may be welfare enhancing or welfare damaging which emphasizes the significance of optimal monetary network design.

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