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Efficient payments: How much do they cost for the Central Bank? ☆

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ABSTRACT

Previous works related to optimal denominations for coins and banknotes consider that the "principle of least effort" that defines an efficient payment is the most important criterion for two main reasons. Firstly, it is more convenient for transactors and, secondly, it limits the production costs of denominations incurred by the central bank. Exploiting production cost data for the U.S. currency system in 2010, we show using simulations that efficient payments actually increase the annual production costs of the Federal Reserve by $156 million. As a consequence, we raise a larger issue for central banks which consists in issuing an efficient denominational mix that is more convenient for transactors and that reduces the production costs of denominations.

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1. Introduction

In recent years, abundant research has been devoted to the study of denominational structures of currency systems (Bouhadoui et al., 2011; Caianiello et al., 1982; Franses and Kippers, 2007; Lee et al., 2005; Sumner, 1993; Telser, 1995; Tschoegl, 1997; Van Hove, 2001; Van Hove and Heyndels, 1996; Wynne, 1997). Among the multiple properties of a currency system, the principle of least effort (PLE) is considered the most important.[2] This principle that defines an efficient payment states that the settlement of cash transactions should involve as few coins and notes as possible.

The preeminence of this principle, supported by many economists such as Boeschoten and Fase (1989), Eriksson and Kokkola (1993), Abrams (1995), Pedersen and Wagener (1996), Van Hove and Heyndels (1996) and Van Hove (2001), is justified by two main arguments. Firstly, the PLE states that it is more convenient for transactors given that it reduces the bulk and weight carried around by the cash-using public in turn limiting handling costs. Secondly, it keeps down the number of coins and notes in circulation and thus, so the reasoning goes, the production costs incurred by the central bank. Following this argument, it is therefore preferable for the central bank to opt for a currency system that limits the number of coins and notes used in transactions.

In this article, we demonstrate that the second argument is biased and that efficient payments increase the production costs incurred by the central bank. Our results tend therefore to support the idea that the private benefits of transactors emphasized in the economic literature can be undermined by the private costs of central banks. To prove this, we proceed in three stages. Firstly, we propose a general framework that links the costs of cash transactions to the production costs of the central bank. Secondly, we compare the costs of cash transactions using the PLE and a hypothetical cost-minimizing payment behavior named the "principle of least cost" (PLC). This latter minimizes the costs of cash transactions without considering the number of tokens exchanged in transactions; this model is only used to identify inefficient payments from the viewpoint of the PLE. Thirdly, we perform simulations on a set of cash transactions using production cost data for the U.S. currency system for the year 2010. The simulation results show that while the number of notes and coins used in transactions is certainly efficient (minimum) with the PLE, the costs of cash transactions are on average 24.2% greater than those obtained with the principle of least cost. Hence, while the PLE keeps down the total number of coins and notes in circulation it can also contribute to an increase in the costs of cash transactions and thus in the production costs of denominations incurred by the central bank. We precisely estimate the increase in the annual production cost to $156 million.

The remainder of the paper is structured as follows. In Section 2, we present the general framework and the cash payment behavior

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[2] Caianiello et al. (1982) point out two other elements, namely the surveyability (variety of denominations) and the compatibility with the decimal system.

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models. In Section 3, we describe the data used to perform simulations and comment on the results obtained. Finally, in Section 4, we discuss the implications of our results.

2. Model

In this section, we first present a general framework that links the costs of cash transactions to the production costs of denominations incurred by the central bank. Next, we present two models of cash payment behavior, namely the principle of least effort and the principle of least cost. Finally, we describe our comparison approach.

2.1. General framework

In a given economy, let set $\mathcal{D}$ be a distribution composed of N_T cash transactions. The distribution $\mathcal{D}$ represents the cash transactions made by the public during a year. To pay in cash the N_T transactions, the agents use a currency system composed of J tokens of face values $v(j)$ with $j \in 1, ..., J$. Regardless of, for the moment, the way people use the denominations in transactions (see below), we denote by k one of the $K(x)$ solutions to pay an amount x. Following this combination, the amount x is paid by exchanging $n_k(x, j)$ token(s) for each denomination j such that:

$$x = \sum_j n_k(x,j) \cdot v(j). \tag{1}$$

The integer $n_k(x, j)$ is set positive when the money is given by the consumer to the merchant and negative when it is a return of change.

Considering all the possible combinations, the average number of times a denomination j is involved in a transaction x is denoted by $a(x, j)$ and called the frequency of use of the denomination j for the amount x:

$$a(x,j) = \frac{1}{K(x)} \cdot \sum_k |n_k(x,j)|. \tag{2}$$

Using Eq. (2), we can define the average frequency of use of a denomination j over the distribution $\mathcal{D}$ as:

$$a(j) = \frac{1}{N_T} \cdot \sum_{x \in \mathcal{D}} a(x,j). \tag{3}$$

Let us now define the usage costs of denominations. To begin with, we assume that the production cost $c_p(j)$ of a denomination includes all the costs and expenses for producing, marketing and distributing coins and notes, and we introduce the depreciation rate per use, $\delta(j)$, of a denomination that captures its deterioration after each use. Multiplying $c_p(j)$ and $\delta(j)$, we can then write the usage cost, $c_u(j)$, of a denomination as:[3]

$$c_u(j) = c_p(j) \cdot \delta(j). \tag{4}$$

The depreciation rate per use of a denomination, $\delta(j)$, depends primarily on the resistance of the manufacturing technology. It can be expressed as a function of the life span, $d(j)$, and the annual velocity of circulation of a denomination, $q_a(j)$, that refers to the average number of times per year a circulating token j is involved in a cash transaction:[4]

$$\delta(j) = \frac{1}{d(j) \cdot q_a(j)}. \tag{5}$$

Likewise, the annual velocity of circulation can be defined as the ratio of the number of uses per year of all the circulating tokens, j, measured with the term $(N_T \cdot a(j))$, and their circulating volume $N_c(j)$:

$$q_a(j) = \frac{N_T \cdot a(j)}{N_c(j)}. \tag{6}$$

Therefore, replacing Eq. (6) in Eq. (5), we obtain:

$$\delta(j) = \frac{N_c(j)}{d(j) \cdot N_T \cdot a(j)}. \tag{7}$$

The central bank is generally responsible of the processing of the currency in circulation. During this operation, the substandard tokens are withdrawn and replaced by new ones. The volume, $N_r(j)$, of tokens of denomination j replaced each year is determined by $N_c(j)$ and $d(j)$:

$$N_r(j) = \frac{N_c(j)}{d(j)}. \tag{8}$$

Then, replacing Eq. (8) with Eq. (7), we have:

$$\delta(j) = \frac{N_r(j)}{N_T \cdot a(j)}. \tag{9}$$

We finally obtain the expression of the usage cost of a denomination, $c_u(j)$, after replacing Eq. (9) with Eq. (4):

$$c_u(j) = \frac{c_p(j) \cdot N_r(j)}{N_T \cdot a(j)}. \tag{10}$$

Using $c_u(j)$, we can finally define the cost of a cash transaction as follows:

$$c_u(x) = \sum_j a(x,j) \cdot c_u(j). \tag{11}$$

The last step of the general framework consists in linking the cost of cash transactions to the production costs of denominations incurred by the central bank. The annual production cost of currency, C_r, incurred by the central bank is by definition related to the new tokens replaced each year, *i.e.*:

$$C_r = \sum_j N_r(j) \cdot c_p(j). \tag{12}$$

Rearranging Eq. (10) and replacing in Eq. (12), one can write:

$$C_r = N_T \cdot \sum_j a(j) \cdot c_u(j). \tag{13}$$

Finally, using Eq. (3) then Eq. (11) with Eq. (13), we obtain:

$$C_r = \sum_x c_u(x). \tag{14}$$

Eq. (14) shows that the costs of cash transactions $c_u(x)$ are directly related to the production costs of denominations incurred by the central bank C_r. As a result, the latter are affected by the way people use denominations in transactions. In the next part, we introduce two models of cash payment behavior.

2.2. Models of cash payment behavior

This part aims at formalizing and comparing two models of cash payment behavior. The first is the "principle of least effort" that we extend to account for the usage costs of denominations. The second one is a hypothetical cost-minimizing model called the "principle of

[3] For instance, if the production cost of a banknote is $c_p(j) = 0.1\$$ and the depreciation rate per use is $\delta(j) = 5\%$ then the usage cost is $c_u(j) = 0.005\$$.

[4] For instance, if $d(j) = 2$ years and $q_a(j) = 5$ uses per year, the depreciation rate per use is $\delta(j) = \frac{1}{2 \times 5} = 10\%$ per use.

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