Money, Credit, and Opportunity Costs*

기회비용에 따른 지급결제수단의 선택과 시사점

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A cash-in-advance model of multiple means of payment is constructed to study the coexistence of multiple means of payment and the effects of opportunity costs and monetary policy. In steady state equilibrium, if the opportunity cost of credit, transactions cost, increases, people hold more cash and use it for a greater variety of goods. Next, if the money growth rate decreases, then the opportunity cost of money, the nominal interest rate, decreases and people use cash for a greater variety of goods. To improve welfare, the government needs to decrease the money stock in order to avoid opportunity costs and the Friedman rule is optimal.

Key Words: credit, Friedman rule, monetary policy, money, opportunity costs, welfare
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I. Introduction

The main objective of this paper is to develop a simple model to explain the coexistence of credit and cash and discuss the effect of the opportunity

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costs of payment instruments and monetary policy on the choice of credit and cash. In practice, there exist several different means of payments such as cash, credit card, debit card, and checks. In market transactions, a consumer chooses a certain instrument which fits the best for their purchases considering its convenience, costs, timing, record-keeping, transactions errors, privacy, security. Thus, an economic change that affects the characteristics of means of payments can make a crucial impact on the choice of means of payments and it is crucial to understand the basic structure of market transactions.

A set of literature provides empirical explanations to the choice of means of payment in US and Korea: Whitesell (1989), Ryu (2007), Schuh and Stavins (2009). Especially, Schuh and Stavins (2009) relates the characteristics of means of payments and the consumer's choice of them. However, they do not have a strong theoretical background why people choose a certain means of payment and use other means of payment if an economic environment changes.

There have been several theoretical studies of the coexistence of multiple means of payment such as Lucas and Stokey (1987), Prescott(1987), Ireland (1994), Lacker and Schreft (1996), and Aiyagari, Braun, and Eckstein (1998). In Lucas and Stokey (1987), cash goods and credit goods exist. A consumer uses cash to purchase cash goods and spends on credit to purchase credit goods. The consumer's choice of means of payment is exogenously fixed and the use of credit does not create transactions costs. Thus, the model cannot explain why a consumer chooses a certain payment instrument over another when purchasing goods. Monetary policy does not affect the choice of means of payment. On the other hand, Prescott (1987), Ireland (1994), Lacker and Schreft (1996), and Aiyagari, Braun, and Eckstein (1998) have developed models where a consumer carries multiple means of payment and chooses a means of payment when acquiring consumption goods. In addition to the nominal interest rate, the opportunity cost of holding cash, they introduce the transactions costs of credit as the opportunity cost of credit. In equilibrium, a consumer purchases some goods with cash and other goods with credit. Cash and credit coexist because a consumer substitutes credit for money if the nominal interest rate increases and he uses more cash if transactions costs increase. A consumer uses credit for larger purchases and cash for smaller ones. Furthermore, Ireland (1994), and Lacker and Schreft (1996) show how credit is substituted for money to purchase a greater variety of goods.

These models of Prescott (1987), Ireland (1994), Lacker and Schreft (1996), and Aiyagari, Braun, and Eckstein (1998) have tried to discuss the implications of economic growth, velocity of income, and asset prices as well as the choice of multiple means of payment. Thus, they hold some features which are not necessary just to study the choice of means of payment. However, this paper constructs a simple model to fully focus attention on the choice of means of payment. Especially, the transactions costs of credit take a specific functional form in order to get clear implications of the effects of a change in transactions costs on the choice of cash and credit.

This paper is built on the model of Ireland (1994) in a way to give more concrete implications about the effects of opportunity costs and monetary policy on the choice of means of payments. A unit mass of households exists and each household consists of a shopper and a worker. Households trade nominal bonds in the asset market and trade consumption goods in the goods market. At the goods market, a shopper can choose what to use as a payment instrument from credit incurring transactions costs and cash. Thus, the opportunity costs of credit and cash are respectively transactions costs and nominal interest. In steady state equilibrium, if the opportunity cost of credit, transactions costs, increases, a shopper holds more cash and uses it for a greater variety of goods. Next, if the money growth rate decreases, then the opportunity cost of money, the nominal interest rate, decreases and a shopper uses cash for a greater variety of goods. To improve welfare, the government needs to decrease the money stock in order to avoid opportunity costs and the Friedman rule is optimal.

The remainder of the paper is organized as follows. Section 2 describes the basic setups. Section 3 and 4 discuss equilibrium and its solutions in steady state. Section 5 presents transactions costs, monetary policy and welfare implications. Section 6 concludes.

II. A Baseline Setup

Time is discrete and indexed by t = 0, 1, 2, ... The economy consists of a continuum of infinitely-lived households with unit mass. Each household consists of two agents: a worker and a shopper. A continuum of spatially separated markets indexed by $i \in [0,1]$ exists at each period. In each market i, a worker produces and sells distinct, perishable consumption goods indexed by $i \in [0,1]$ in every period. The household has preferences given by

$$U(\{c_t, x_t\}_{t=0}^{\infty}) = \sum_{t=0}^{\infty} \beta^t \left\{ \int_0^1 ln(c_t(i))di - x_t \right\}$$

where β is the discount factor; $c_t(i)$ represents consumption goods purchased at market i at time t; x_t represents transactions costs.

At the beginning of each period t, each household enters the period with M_t units of currency and B_t units of one-period nominal bonds. Then, the household learns the money growth rate, θ_t. The government controls the nominal money supply through nominal lump-sum transfers, $P_t\tau_t$ and the government budget constraint is

$$M^s_{t+1} = M^s_t + P_t\tau_t$$
$$M^s_{t+1} = \theta M^s_t \ .$$

where P_t is the average price level of consumption goods.

The asset market opens and each household trades one-period nominal bonds, B_t, and money. Each bond sells for q_t units of money in period t and is a claim to one unit of money in period $t+1$. The asset market closes and a worker and a shopper at each household leave for a goods market.

At the goods market, a worker and a shopper start to exchange consumption goods. A worker sells endowments, y, and a shopper travels from market to market purchasing consumption good i. When a shopper purchases goods, he has two ways of acquiring goods in market i. One is to use non-interest bearing currency that has the gross nominal interest rate, R_t, as an opportunity cost.

The other is to spend on credit, incurring transactions costs,

$$\gamma(i) = ln\left(\frac{\alpha i}{1-i}\right), \tag{1}$$

where $\gamma(\mathrm{i}) \geq 0$ is increasing, differentiable on i, $\gamma(0) = 0$, $\lim_{t \to 1} \gamma(\mathrm{i}) = 1$, and α is the degree of transactions costs. There is no transactions costs if a shopper does not spend anything on credit. However, if a shopper uses credit in every market i, then transactions costs goes infinity. That is, as a consumer spends on credit more and more, transactions costs for purchasing goods go infinity. For example, if a consumer continues to use credit for each market, then eventually he gets a market which experiences technical difficulties to identify the user's credit history or where his credit limit is used up. The coefficient α can represent the level of waiting time to check credit history, membership fees paid to the credit card company, or credit limit. Transactions costs appear as effort in the household's preferences and a shopper takes it as household disutility,

$$x_t(i) = \int_0^1 \xi_t(i) ln\left(\frac{\alpha i}{1-i}\right) di,$$

where $\xi_t(i)$ is an indicator variable: $\xi_t(i) = 1$, if shoppers use credit to buy good i at time t and $\xi_t(i) = 0$, if shoppers use currency to buy good i at time t. The cash-in-advance constraint in the goods market is

$$\int_0^1 P_t(i)(1-\xi_t(i))c_t(i)di \leq M_t + P_t\tau_t - q_tB_{t+1}B_t.$$

where $P_t(i)$ is the price of consumption good i.

At the end of each period, all agents return home. A worker brings the revenue of sales, P_ty_t back home. No further trade or barter is allowed. The household budget constraint is

$$\int_0^1 P_t(i)c_t(i)di + M_{t+1} = M_t + P_t\tau_t - q_tB_{t+1} + B_t + P_ty.$$

III. Optimization

The household solves the following optimization problem: for all i,

$$\max_{c_t(i),\xi_t(i),m_{t+1},b_{t+1}} \sum_{t=0}^{\infty}\beta^t\left\{\int_0^1 ln(c_t(i))di-\int_0^1 \xi_t(i)ln\left(\frac{\alpha i}{1-i}\right)di\right\}$$

subject to

$$\int_0^1 p_t(i)(1-\xi_t(i))c_t(i)di \le m_t+p_t\tau_t-\theta_t q_t b_{t+1}+b_t \qquad (2)$$

$$\int_0^1 p_t(i)c_t(i)di+\theta_t m_{t+1}=m_t+p_t\tau_t-\theta_t q_t b_{t+1}+b_t+p_t y \qquad (3)$$

$$m_{t+1}\ge 0 \qquad (4)$$

$$b_{t+1}\ge b \qquad (5)$$

where inequality (4) is the nonnegativity constraints and inequality (5) is the no Ponzi-scheme constraint. Note that nominal variables are divided by M_s^t to make the household's dynamic optimization problem stationary.

Definition: A competitive equilibrium consists of the sequences $\{c_t(i)$, x_t, $\xi_t(i)$, m_{t+1}, b_{t+1}, M_{t+1}^s, $p_t(i)$, τ_t, $R_t\}$ for all t, where $i\in[0\ 1]$ such that:

1. $\{c_t(i)$, x_t, $\xi_t(i)$, m_{t+1}, $b_{t+1}\}$ solves the household's problem given $\{M_{t+1}^s$, $p_t(i)$, τ_t, $R_t\}$.
2. Markets clear in every period:

(a) Bond Market: $b_{t+1}=0$,

(b) Money Market: $m_{t+1}=1$,

(c) Goods Market: for each market i,

$$y=\int_0^1 c_t(i)d_i,$$

(d) $m_t + p_t\tau_t = \theta_t$,

where no one will hold any nominal bonds in equilibrium since all households are identical.

Drop t subscripts and let primes denote variables dated $t+1$. The household's optimization problem translates into the following dynamic programming problem:

$$v(m,b;\theta) = \max_{c,x,\xi,\, m',b'} \int_0^1 ln(c(i))di - \int_0^1 \xi(i)\gamma(i)di + \beta v(m',b';\theta)$$

subject to equations (1) - (5).

Ⅳ. Steady State Equilibrium

This section will focus attention on the steady state equilibrium where for example, in the long run $c_t(i) = c(i)$, $x_t = x$, $\xi_t(i) = \xi(i)$, $m_{t+1} = m$, $b_{t+1} = b$, and $p_t(i) = p(i)$. In steady state equilibrium, the choices of $c(i)$ is as follows assuming λ_1 and λ_2 denote the Lagrange multipliers to the cash-in-advance constraint and the budget constraint:

$$\frac{1}{c(i)} - \lambda_1(1-\xi(i))p - \lambda_2 p = 0,$$

$$\frac{1}{c^1(i)} - \lambda_2 p = 0 \quad , \text{ if } \xi(i) = 1, \tag{6}$$

$$\frac{1}{c^0(i)} - (\lambda_1+\lambda_2)p = 0 \quad , \text{ if } \xi(i) = 0, \tag{7}$$

where $c^1(i)$ is consumption with credit and $c^0(i)$ is consumption with cash and in equilibrium, $p(i)=p$ for all market i holds. At the goods market, each shopper faces the same marginal utility of consumption across market i, so for all i, j ∈ [0; 1],

$$c(i)p(i)=c(j)p(j).$$

Since $c(i) = y$ for each market i and y is independent from market i, every market should sell goods at the same price, $p(i) = p$ for all i.

The decision of $\xi_t(i)$ comes from a tradeoff between the transactions costs of credit, $\gamma(i)$, and the opportunity cost of holding money, $c^0(\mathrm{i})\lambda_1$:

$$\xi(i)=\begin{cases} 1, & \text{if } ln(c^1(i))-\gamma(i)-\lambda_2 c^1(i)p \\ & \quad > ln(c^0(i))-c^0(i)(\lambda_1+\lambda_2)p, \\ 0, & \text{if } ln(c^1(i))-\gamma(i)-\lambda_2 c^1(i)p \\ & \quad < ln(c^0(i))-c^0(i)(\lambda_1+\lambda_2)p, \end{cases} \tag{8}$$

where

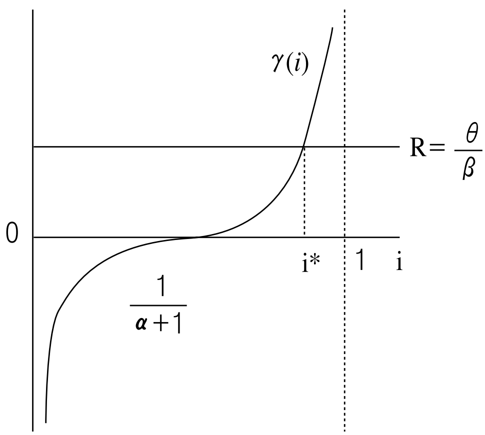
$$\gamma(i)=ln\left(\frac{\alpha i}{1-i}\right).$$

A shopper picks credit to purchase good i when the marginal benefit of using credit, $ln(c^1(i))-\gamma(i)-\lambda_2 c^1(i)p$, is greater than that of using cash, $ln(c^0(i))-c^0(i)(\lambda_1+\lambda_2)p$. On the other hand, a shopper picks cash if the marginal benefit of using cash is greater than the marginal benefit of using credit. Thus, in equations (8), a cutoff, $i^*(\theta)$, between credit and cash choices is determined as

$$\frac{\alpha i^*}{1-i^*}=\frac{c^1}{c^0}, \tag{9}$$

where transactions costs are equal to the marginal rate of substitution of c^0 for c^1. A higher i¤ implies a higher marginal rate of substitution of c^0 for c^1. A shopper replaces credit for cash and purchases a larger variety of goods with credit in the market. In other words, a shopper uses credit to acquire good i where $i < i^*$ and uses cash to acquire good i where $i > i^*$.

〈Figure 1〉 The Credit-Cash Cutoff



The choices of m′ and b', in equilibrium, are as follows:

$$\beta(\lambda'_1 + \lambda'_2) = \lambda_2 \theta; \tag{10}$$

$$\beta(\lambda'_1 + \lambda'_2) = (\lambda_1 + \lambda_2)\theta q. \tag{11}$$

In steady state, the list of variables is constant and equations (10) and (11) become

$$\frac{\beta}{\theta}(\lambda_1+\lambda_2)=\lambda_2 \tag{12}$$

and with equation (11), the nominal interest rate is positive

$$R=\frac{1}{q}=\frac{\theta}{\beta}> 1, \tag{13}$$

if the cash-in-advance constraint binds, $\lambda_1 > 0$. A shopper economizes his cash holding if the nominal interest rate is positive.

Given equations (6), (7), and (12), consumption with credit, c^1, is greater than consumption with money, c^0:

$$c^0(\lambda_2,\ \theta)=\left\{c^*\,|\,c^*=\frac{\beta}{\theta}\,\frac{1}{\lambda_2 p}\right\}, \tag{14}$$

$$c^1(\lambda_2,\ \theta)=\left\{c^*\,|\,c^*=\frac{1}{\lambda_2 p}\right\}. \tag{15}$$

A shopper using the same means of payment for some market i acquires the same amount of consumption goods, i.e. $c^0=c^0(i)$ and $c^1=c^1(i)$, because the marginal value of cash is the same across markets and so is the marginal value of wealth. Besides, the volume of one specific consumption good purchased by credit at market i is independent of transactions costs. Transactions costs increase only when the household purchases a greater variety of consumption goods with credit. Therefore, aggregate consumption and transactions costs simplify as follows:

$$\int_0^1 c(i)di=\int_0^{i^*} c^1(i)di+\int_{i^*}^1 c^0(i)di=i^*c^1+(1-i^*)c^0,$$

$$\int_0^1 \xi(i)\gamma(i)di = \int_0^{i^*} \gamma(i)di,$$

where

$$\gamma(i) = ln\left(\frac{\alpha i}{1-i}\right)$$

and the goods market clearing condition becomes

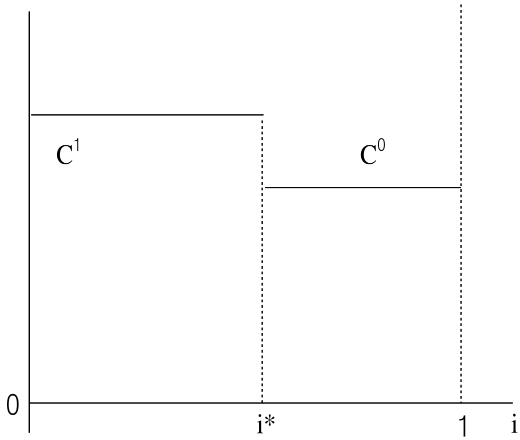
$$i^* c^1 + (1-i^*)c^0 = y.$$

Furthermore, in equations (14) and (15), the marginal rate of substitution of c^0 for c^1 depends on the nominal interest rate as of Lucas and Stokey (1987), Prescott (1987), Ireland (1994), and Lacker and Schreft (1996):

$$\frac{c^1}{c^0} = \frac{\theta}{\beta} \tag{16}$$

where the cash-in-advance constraint binds, $\theta > \beta$. A shopper spends on credit for larger purchases and uses cash for smaller purchases, $c^1 > c^0$. The opportunity cost of money, nominal interest, increases as the volume of a good i purchased with money increases. However, the transactions costs of credit does not increases although the volume of a good i purchased with credit increases. The transactions costs of credit increases as a shopper spends on credit for a greater variety of goods. Therefore, a shopper would rather spend on credit not to lose nominal interest as the volume of a good i purchased increases.

〈Figure 2〉 Consumption with Credit and Cash



Suppose the real money balance, θ/p, that shoppers decide to carry to the next period is a fraction of the revenue of sales, φy:

$$\frac{\theta}{p}=\varphi y.$$

Then, binding cash-in-advance and budget constraints,

$$p(1-i^*)c^0=\theta,$$

and

$$pi^*c^1=py-\theta,$$

imply that total consumption with credit and cash is

$$(1-i^*)c^0=\varphi y \tag{17}$$

$$i^*c^1=(1-\varphi)y. \tag{18}$$

Therefore, in equations (9) and (16), the solution for the choice of cash and credit is determined as follows:

$$i^* = \frac{1}{1 + \frac{\alpha\beta}{\theta}}, \tag{19}$$

Then, equations (16) - (18) imply the solution for real cash holding to the next period such as

$$\varphi = \frac{1}{1 + \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2}. \tag{20}$$

Finally, in equations (17) - (20), consumption with cash and credit is

$$c^1 = \left(\frac{\frac{\theta}{\beta} + \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2}{1 + \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2}\right) y, \tag{21}$$

$$c^0 = \left(\frac{1 + \frac{\theta}{\alpha\beta}}{1 + \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2}\right) y. \tag{22}$$

V. Implications

1. Transactions Costs

In equations (1), α is the coefficient of transactions costs which affects the degree of costs for all i. If α increases, then a shopper pays more costs when he spends on credit to purchase a good i. In equations (19) and (20), it is clear to check the effects of transactions costs, α, on the choice of credit and cash and the real money balances:

$$\frac{\partial i^*}{\partial \alpha} < 0 ,$$

$$\frac{\partial \varphi}{\partial \alpha} > 0 .$$

Given the money growth rate, θ, an increase in the transactions costs makes the opportunity cost of credit relatively more expensive than that of cash. A shopper purchases a less variety of goods with credit and his real money balances increase since he uses cash for a greater variety of goods. On the other hand, if α decreases, then a shopper uses credit for greater variety of goods and holds less cash.

In equations (21) and (22), the effects of transactions costs, α, on consumption with credit and cash are

$$\frac{\partial c^1}{\partial \alpha} = \frac{y\left(\frac{\theta}{\beta}\right)^2\left(\frac{\theta}{\beta} - 1\right)}{\left\{\alpha + \left(\frac{\theta}{\beta}\right)^2\right\}^2} > 0 , \tag{23}$$

$$\frac{\partial c^0}{\partial \alpha} = \frac{y\frac{\theta}{\beta}\left(\frac{\theta}{\beta} - 1\right)}{\left\{\alpha + \left(\frac{\theta}{\beta}\right)^2\right\}^2} > 0 , \tag{24}$$

where

$$\theta > \beta .$$

Note that the transactions costs, $\gamma(i)$, have an effect not on the volume of consumption with credit once a shopper decides to pay them. Thus, an increase in α decreases the variety of consumption with credit, but it increases the volume of it to compensate the loss of variety. However, the nominal interest rate, R, has an effect both on the volume and variety of consumption with cash. Thus, a shopper acquires more consumption goods with credit and with cash if the relative price of using credit increases due to a greater α. On the other hand, a shopper consumes more with credit and consumes less with cash if α decreases.

2. Monetary Policy and Welfare

This section will study how the choice of means of payments reacts along with monetary policy. First, the effects of monetary policy on cash-credit choice, i^*, and real money balances, φ, are

$$\frac{\partial i^*}{\partial \theta} > 0,$$

$$\frac{\partial \varphi}{\partial \theta} < 0.$$

When the government increases money supply, inflation arises in the economy. The value of money decreases, but the nominal interest rate, θ/β, increase. The opportunity cost of holding cash increase, so a shopper holding less cash will spend more on credit. On the other hand, if the government decreases money supply, the opportunity cost of holding money decreases due to a lower nominal interest rate. A shopper holding more cash will use it for a greater variety of goods.

In equations (21) and (22), the effects of transactions costs, α, on consumption with credit and cash are

$$\frac{\partial c^1}{\partial \theta} = \frac{y\alpha\beta\left(\frac{\beta}{\theta} - 1\right)}{\theta^2\left\{1 + \alpha\left(\frac{\beta}{\theta}\right)^2\right\}^2} < 0, \tag{25}$$

$$\frac{\partial c^0}{\partial \theta} = \frac{-y\left\{\frac{1}{\alpha}\left(\frac{\theta}{\beta} - 1\right)^2 + \left(\frac{1}{\alpha} + 1\right)\left(\frac{2\theta}{\beta} - 1\right)\right\}}{\alpha\beta\left\{1 + \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right\}^2} < 0, \tag{26}$$

where

$\theta > \beta$.

An expansionary monetary policy decreases consumption with credit and cash. Inflation increases the nominal interest rate and the relative price of credit becomes more cheaper than that of cash. A shopper consumes a greater variety of goods with credit and decreases the volume of each good i purchased with credit. However, a shopper decreases consumption with cash simply due to a higher nominal interest rate.

Given the choice of credit and cash, the real money holding, and consumption with credit and cash in equations (19) – (22), the government can choose the money growth rate to maximize the following welfare,

$$W = \max_{\theta} \{i^* ln(c^1) + (1-i^*) ln(c^0) - \int_0^{i^*} ln(\frac{\alpha i}{1-i}) di\}. \tag{27}$$

The effects of the money growth rate on welfare shows that welfare decreases as the money growth rate increase: for $\theta > \beta$,

$$\frac{\partial W}{\partial \theta} = \frac{2\left(1 - \frac{\theta}{\beta}\right)}{(\theta + \alpha\beta)\left(1 + \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right)} < 0. \tag{28}$$

In other words, the government needs to decrease the money stock in order to encourage a shopper to use cash and decrease transactions costs incurred by credit. There exists welfare costs of inflation since inflation decreases the value of money and increases the opportunity cost of money, the nominal interest rate. The use of credit increases and it incurs larger transactions costs. Therefore, even with credit, inflation decreases welfare.

The optimal money growth rate, where $\delta W/\delta\theta = 0$, is

$$\theta^* = \beta.$$

The economy becomes inefficient once a shopper economizes his cash and the

government should decrease the money stock by the rate of the discount factor. Thus, the Friedman rule is optimal.

VI. Conclusion

This paper develops a simple model to explain the coexistence of credit and cash and to discuss the effects of opportunity costs of payment instruments and monetary policy on the choice of credit and cash. A unit mass of households exists and each household consists of a shopper and a worker. Households trade nominal bonds in the asset market and trade consumption goods in the goods market. At the goods market, a shopper can choose what to use as a payment instrument from credit incurring transactions costs and cash. Thus, the opportunity costs of credit and cash are respectively transactions costs and nominal interest. In steady state equilibrium, if the opportunity cost of credit, transactions costs, increases, a shopper holds more cash and uses it for a greater variety of goods. Next, if the money growth rate decreases, then the opportunity cost of money, the nominal interest rate, decreases and a shopper uses cash for a greater variety of goods. To improve welfare, the government needs to decrease the money stock in order to avoid opportunity costs and the Friedman rule is optimal.

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요 약

본 연구에서는 다양한 지급결제수단이 존재하는 이유에 대해서 분석하면서 이들에 대한 소비자의 지급결제수단의 선택이 외부 환경 변화에 어떻게 반응하는지 이론적인 시사점을 제시하고자 한다. 일반균형이론에서 시장에서 소비자가 현금과 신용카드 중 적합한 것을 지급수단으로 선택할 수 있는 Cash-In-Advance 모형을 구축하였다. 현금을 사용할 때 발생하는 기회비용은 명목이자가 되고, 신용카드를 사용할 때 발행하는 기회비용은 거래비용으로 나타난다. 우선, 신용카드의 거래비용이 증가하게 되면 소비자는 신용카드의 사용을 줄이고, 현금보유량을 늘려 많은 거래를 현금으로 한다. 반면에 정부가 통화량을 증가시키면 명목이자율이 올라가면서 현금의 기회비용이 증가하게 된다. 소비자들은 현금보유량을 줄이게 되고, 많은 거래를 신용카드로 하게 된다. 정부는 신용카드로부터 발생하는 거래비용을 줄임으로써 경제 전반의 효용을 증가시킬 수 있으므로, 통화량을 줄여나가는 것이 최적이다.

※ 국문 색인어: 기회비용, 신용카드, 통화정책, 프리드만 룰, 현금, 효용

【Appendix】

A. Derivation of equation (23)

Consumption with credit in equation (21) can be expressed as follows by multiplying both the numerator and denominator by α:

$$c^1 = \left(\frac{\alpha\left(\frac{\theta}{\beta}\right) + \left(\frac{\theta}{\beta}\right)^2}{\alpha + \left(\frac{\theta}{\beta}\right)^2} \right) y\,. \tag{29}$$

The derivative of equation (29) with respect to α is

$$\frac{\partial c^1}{\partial \alpha} = \frac{y\left\{ \frac{\theta}{\beta}\left(\alpha + \left(\frac{\theta}{\beta}\right)^2\right) - \alpha\frac{\theta}{\beta} - \left(\frac{\theta}{\beta}\right)^2 \right\}}{\left\{\alpha + \left(\frac{\theta}{\beta}\right)^2\right\}^2}$$

$$= \frac{y\left(\frac{\theta}{\beta}\right)\left\{\alpha + \left(\frac{\theta}{\beta}\right)^2 - \alpha - \frac{\theta}{\beta}\right\}}{\left\{\alpha + \left(\frac{\theta}{\beta}\right)^2\right\}^2}$$

$$= \frac{y\left(\frac{\theta}{\beta}\right)^2\left(\frac{\theta}{\beta} - 1\right)}{\left\{\alpha + \left(\frac{\theta}{\beta}\right)^2\right\}^2} > 0\,,$$

where

$$\theta > \beta.$$

B. Derivation of equation (24)

Consumption with cash in equation (21) can be expressed as follows by multiplying both the numerator and denominator by α:

$$c^0 = \left(\frac{\alpha + \frac{\theta}{\beta}}{\alpha + \left(\frac{\theta}{\beta}\right)^2} \right) y. \tag{30}$$

The derivative of equation (30) with respect to α is

$$\frac{\partial c^0}{\partial \alpha} = \frac{y\left\{\alpha + \left(\frac{\theta}{\beta}\right)^2 - \alpha - \frac{\theta}{\beta}\right\}}{\left\{\alpha + \left(\frac{\theta}{\beta}\right)^2\right\}^2}$$

$$= \frac{y\frac{\theta}{\beta}\left(\frac{\theta}{\beta} - 1\right)}{\left\{\alpha + \left(\frac{\theta}{\beta}\right)^2\right\}^2} > 0 \ ,$$

where

$$\theta > \beta.$$

C. Derivation of equation (25)

Consumption with credit in equation (21) can expressed as follows by dividing both the numerator and denominator into $(1/\alpha)(\theta/\beta)^2$:

$$c^1 = \left(\frac{1+\alpha\left(\frac{\beta}{\theta}\right)}{1+\alpha\left(\frac{\beta}{\theta}\right)^2} \right) y. \tag{31}$$

The derivative of equation (31) with respect to θ is

$$\frac{\partial c^1}{\partial \theta} = \frac{y\left\{\frac{-\alpha\beta}{\theta^2}\left(1+\alpha\left(\frac{\beta}{\theta}\right)^2\right)+\left(1+\frac{\alpha\beta}{\theta}\right)\frac{2\alpha\beta^2}{\theta^2}\right\}}{\left\{1+\alpha\left(\frac{\beta}{\theta}\right)^2\right\}^2}$$

$$= \frac{y\left(\frac{\alpha\beta}{\theta^2}\right)\left\{-1-\alpha\left(\frac{\beta}{\theta}\right)^2+\frac{\beta}{\theta}\left(1+\frac{\alpha\beta}{\theta}\right)\right\}}{\left\{1+\alpha\left(\frac{\beta}{\theta}\right)^2\right\}^2}$$

$$= \frac{y\alpha\beta\left(\frac{\beta}{\theta}-1\right)}{\theta^2\left\{1+\alpha\left(\frac{\beta}{\theta}\right)^2\right\}^2} < 0,$$

where

$$\theta > \beta.$$

D. Derivation of equation (26)

The derivative of equation (22) with respect to θ is

$$\frac{\partial c^0}{\partial \theta} = \frac{y\left\{\frac{1}{\alpha\beta}\left(1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right)-\left(1+\frac{\theta}{\alpha\beta}\right)\frac{2\theta}{\alpha\beta^2}\right\}}{\left\{1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right\}^2}$$

$$= \frac{y\left\{1-\frac{2\theta}{\beta}-\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right\}}{\alpha\beta\left\{1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right\}^2}$$

$$= \frac{-y\left\{\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2-\frac{2\theta}{\alpha\beta}+\frac{2\theta}{\alpha\beta}+\frac{2\theta}{\beta}-1\right\}}{\alpha\beta\left\{1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right\}^2}$$

$$= \frac{-y\left\{\frac{1}{\alpha}\left(\frac{\theta}{\beta}-1\right)^2-\frac{1}{\alpha}+\frac{2\theta}{\alpha\beta}+\frac{2\theta}{\beta}-1\right\}}{\alpha\beta\left\{1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right\}^2}$$

$$= \frac{-y\left\{\frac{1}{\alpha}\left(\frac{\theta}{\beta}-1\right)^2-\left(\frac{2\theta}{\alpha\beta}-1\right)\left(\frac{1}{\alpha}+1\right)\right\}}{\alpha\beta\left\{1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right\}^2} < 0,$$

where

$$\theta > \beta.$$

E. Derivation of inequality (28)

Welfare measure in equation (27) can be expressed as follows:

$$W = i^* ln\left(\frac{c^1}{c^0}\right) + ln(c^0) - \int_0^{i^*} ln\left(\frac{\alpha i}{1-i}\right) di$$

$$= i^* ln\left(\frac{c^1}{c^0}\right) + ln(c^0) - i^* ln(\alpha) - i^* ln(i^*) + 1 - (1-i^*) ln(1-i^*)$$

$$= i^* ln\left(\frac{\alpha i^*}{1-i^*}\right) + ln(c^0) - i^* ln\left(\frac{\alpha i^*}{1-i^*}\right) + 1 - ln(1-i^*)$$

$$= 1 + ln(c^0) - ln(1-i^*) \tag{32}$$

where

$$\int_0^{i^*} ln\left(\frac{\alpha i}{1-i}\right) di = \int_0^{i^*} ln(\alpha) di + \int_0^{i^*} ln(i) di - \int_0^{i^*} ln(1-i) di$$

$$= i^* ln(\alpha) - i^* + i^* ln(i^*) - (1-i^*) + (1-i^*) ln(1-i^*)$$

$$= i^* ln(\alpha) + i^* ln(i^*) - 1 + (1-i^*) ln(1-i^*)$$

and in equation (9),

$$ln\left(\frac{c^1}{c^0}\right) = ln\left(\frac{\alpha i^*}{1-i^*}\right).$$

The derivative of welfare in equation (32) is

$$\frac{\partial W}{\partial \theta} = \left(\frac{1}{c^0}\right)\frac{\partial c^0}{\partial \theta} + \left(\frac{1}{1-i^*}\right)\frac{\partial i^*}{\partial \theta}. \tag{33}$$

The first term of equation (33) can be expressed as

$$\left(\frac{1}{c^0}\right)\frac{\partial c^0}{\partial \theta}=\left\{\frac{1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2}{\left(1+\frac{\theta}{\alpha\beta}\right)y}\right\}\ \frac{-y\left(\frac{1}{\alpha}\left(\frac{\theta}{\beta}-1\right)^2+\left(\frac{1}{\alpha}+1\right)\left(\frac{2\theta}{\beta}-1\right)\right)}{\alpha\beta\left(1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right)^2}$$

$$=\left(\frac{-1}{(\alpha\beta+\theta)}\right)\ \frac{\left(\frac{1}{\alpha}\left(\frac{\theta}{\beta}-1\right)^2+\left(\frac{1}{\alpha}+1\right)\left(\frac{2\theta}{\beta}-1\right)\right)}{1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2}$$

$$=\ \frac{-\frac{1}{\alpha}\left(\frac{\theta}{\beta}-1\right)^2\left(\frac{1}{\alpha}+1\right)\left(\frac{2\theta}{\beta}-1\right)}{(\alpha\beta+\theta)\left(1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right)}$$

$$=\ \frac{-\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2+\frac{2\theta}{\alpha\beta}-\frac{1}{\alpha}-\frac{2\theta}{\alpha\beta}-\frac{2\theta}{\beta}+\frac{1}{\alpha}+1}{(\alpha\beta+\theta)\left(1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right)}$$

$$=\ \frac{-\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2-\frac{2\theta}{\beta}+1}{(\alpha\beta+\theta)\left(1+\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right)} \tag{34}$$

The second term of equation (33) can be expressed as

$$\left(\frac{1}{1-i^*}\right)\frac{\partial i^*}{\partial \theta}=\frac{\left(1+\frac{\theta}{\alpha\beta}\right)\frac{\alpha\beta}{\theta^2}}{\left(1+\frac{\alpha\beta}{\theta}\right)^2}=\frac{\left(1+\frac{\alpha\beta}{\theta}\right)}{\theta\left(1+\frac{\alpha\beta}{\theta}\right)^2}=\frac{1}{(\alpha\beta+\theta)} \tag{35}$$

Equations (33) – (35) characterizes the monetary policy effect on welfare as follows:

$$\frac{\partial W}{\partial \theta} = \left(\frac{1}{c^0}\right)\frac{\partial c^0}{\partial \theta} + \left(\frac{1}{1-i^*}\right)\frac{\partial i^*}{\partial \theta}$$

$$= \frac{-\frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2 - \frac{2\theta}{\beta} + 1}{(\alpha\beta + \theta)\left(1 + \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right)} + \frac{1}{(\alpha\beta + \theta)}$$

$$= \frac{1 + \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2 - \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2 - \frac{2\theta}{\beta} + 1}{(\alpha\beta + \theta)\left(1 + \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right)}$$

$$= \frac{2\left(1 - \frac{\theta}{\beta}\right)}{(\alpha\beta + \theta)\left(1 + \frac{1}{\alpha}\left(\frac{\theta}{\beta}\right)^2\right)} < 0,$$

where

$$\theta \rangle \beta.$$