Joint Discussion Paper Series in Economics

by the Universities of

Aachen · Gießen · Göttingen
Kassel · Marburg · Siegen

ISSN 1867-3678

No. 05-2022

Max Fuchs and Jochen Michaelis

Is a Secondary Currency Essential? – On the Welfare Effects of a New Currency

Coordination: Bernd Hayo • Philipps-University Marburg
School of Business and Economics • Universitätsstraße 24, D-35032 Marburg
Tel: +49-6421-2823091, Fax: +49-6421-2823088, e-mail: hayo@wiwi.uni-marburg.de

Is a secondary currency essential? - On the welfare effects of a new currency

Max Fuchs*

Jochen Michaelis†

February 15, 2022

Abstract: The coexistence of cash and digital currencies constitutes a system of parallel currencies. This paper tackles the question whether a new (digital) currency is essential: Does a new currency allow for a better resource allocation even if a fully accepted currency is in circulation and still remains in circulation? Using the dual currency search model of Kiyotaki and Wright (1993), we show how the introduction of a secondary currency affects average utility. There is some scope for a welfare improvement, the welfare effect depends on differences in returns and costs, and, in particular, the fraction of cash traders who will be replaced by digital money traders.

JEL classification: E41, E42, E51

Keywords: digital money, dual currency regime, welfare comparison

*University of Kassel, Department of Economics, Nora-Platiel-Straße 4, 34127 Kassel, Germany, max.fuchs@uni-kassel.de

†University of Kassel, Department of Economics, Nora-Platiel-Straße 4, 34127 Kassel, Germany, michaelis@wirtschaft.uni-kassel.de

1 Introduction

The process of digitalization accelerates the emergence of new currencies such as cryptocurrencies, corporate currencies and central bank digital currencies. These currencies may serve as additional medium of exchange, they are new competitors on the markets for liquidity services. Kiyotaki and Wright (1993) have shown that fiat money is essential, i.e., compared to a barter economy fiat money allows for a better resource allocation. In this paper, we put forward a similar question: Is the secondary currency essential too? Does the introduction of a new currency allow for a welfare improvement even if a fully accepted currency is in circulation and still remains in circulation? To tackle this question, we use the dual currency search framework of Kiyotaki and Wright (1993). The answer we find is a limited yes. Not surprisingly, the scope for a welfare improvement depends on differences in returns and costs. But in addition, the sign of the welfare effect very much depends on the fraction of cash traders who will be replaced by digital money traders, or, equivalently, the degree of substitution between the new digital currency and the traditional currency.

The focus of our model is an advanced economy with a well-functioning payment system. We have in mind the Eurozone and/or the United States, where cash is an established medium of exchange and where now a cryptocurrency such as Bitcoin or a corporate currency such as Libra/Diem emerges. Another example is Switzerland, where the Euro is accepted in most parts of the country despite the universal acceptance of the Swiss franc. We do not believe in a cashless society, our framework thus assumes that cash as traditional currency remains in circulation even if the new currency is fully accepted. We do not model the process of currency substitution with the use of the new currency instead of cash. Such a full crowding out of the domestic currency is more relevant for high-inflation countries and countries with eroding economic and political institutions. The use of multiple currencies during turbulent times, studied and surveyed in, e.g., Calvo and Vegh (1992), Giovannini and Turtelboom (1994), Selcuk (2003) and Airaudo (2014), is no equilibrium phenomenon, so that the Kiyotaki-Wright framework is not appropriate. Note, however, the different view of Colacelli and Blackburn (2009), who employ the dual currency approach to investigate the multiple currency usage during the Great Depression in the United States and the 2002 recession in Argentina.

The coexistence of both cash and the secondary currency has to be an equilibrium outcome. The Kiyotaki-Wright framework shows this desirable feature. Moreover, this framework allows for the distinction between partial and full acceptance of the secondary currency. For different modelling approaches, we refer to the overlapping generation model of Lippi (2021), the currency competition model of Schillig and Uhlig (2019), and the New Keynesian framework of Uhlig and Xie (2020).

The economics of dual currency regimes is the topic of a wide body of theoretical and empirical literature. An excellent overview of the search-theoretic foundations of the use of multiple currencies is presented by Craig and Waller (2000). Aiyagari et al. (1996) study the coexistence of money and interest-bearing securities, Curtis and Waller (2000) focus on the simultaneous use of legal and illegal currencies, Camera et al. (2004) distinguish between safe and risky fiat monies, Lotz (2004) addresses the question how to regulate a new currency. Ding and Puzello (2020) use laboratory experiments to explore how governmental interventions such as legal restrictions on the use of a foreign currency or a change in using costs affect the circulation of the domestic currency. Also using a laboratory experimental design, Rietz (2019) analyses the determinants of the acceptance rate of a secondary currency.

Surprisingly, all these studies say very little about the scope of a welfare-improvement of a secondary currency. This paper aims to fill this gap. The remainder of the paper is organized as follows. Section 2 describes the model setup of our analysis. Section 3 presents the single currency regime as benchmark economy. Section 4 discusses two switching scenarios, we distinguish between partial und full acceptance of the new currency. Section 5 concludes.

2 The Setup

The economy consists of a continuum of infinitely lived agents with population size normalized to unity. We follow Matsuyama et al. (1993) and assume that agents of type $i \in \{1, ..., I\}$, with $I \geq 3$, only consume goods of type i, but produce goods of type $i+1$ (modulo I). As a consequence, there is no double coincidence of wants and no pure barter in the economy. Thus, money is necessary for trading.

Besides the consumption goods, the economy is endowed with two types of money, cash and digital money. We thus distinguish between three trading states: agents are cash traders, digital money traders or commodity traders. Let μ_C and μ_D be the fraction of agents endowed with one unit of cash and digital money, respectively. The fraction of agents endowed with a commodity, μ_S, then is $\mu_S = 1 - \mu_C - \mu_D$. We treat these fractions as exogenous parameters.

Meetings are pairwise and occur according to a Poisson process with constant arrival rate β, with $\frac{\beta}{I} = 1$. Let V_j, $j = S, C, D$, be the value functions of a commodity trader (seller S), a cash trader C and a digital money trader D, and let $r > 0$ denote the agent's rate of time preference. The expected returns to search are then given by the Bellman equations

$$rV_S = \mu_C \max_{\pi_C(i)}[\pi_C(i)(V_C - V_S)] + \mu_D \max_{\pi_D(i)}[\pi_D(i)(V_D - V_S)] \tag{1}$$

$$rV_C = \gamma_C + \mu_S \Pi_C(U - \eta_C + V_S - V_C) \tag{2}$$

$$rV_D = \gamma_D + \mu_S \Pi_D(U - \eta_D + V_S - V_D). \tag{3}$$

The flow return to a seller is the sum of two terms. The first term is the probability of meeting a cash trader, μ_C, times the probability of accepting cash, $\pi_C(i)$, times the gain of accepting cash, $V_C - V_S$. Note that $\pi_C(i)$ is chosen optimally by agent i. The second term is the probability of meeting a digital money trader, μ_D, times the optimally chosen probability of accepting digital money, $\pi_D(i)$, times the gain of accepting digital money, $V_D - V_S$. If the return of switching the state is positive (negative), seller i always accepts (rejects) the currencies and sets the optimal response $\pi_C(i)$ respective $\pi_D(i)$ to unity (zero). If sellers are indifferent between states, they flip a coin with $0 < \pi_C(i), \pi_D(i) < 1$, a currency is partially accepted[1]. Since, by assumption, there is no pure barter and no consumption of the commodity sellers are endowed with, a positive flow return to a seller requires a switch of status from a commodity to a money trader.

For a cash trader, the expected return from trading is equal to the probability of meeting a seller, μ_S, times the overall acceptance of cash, Π_C, times the gain of consuming and switching status from C to S, $U - \eta_C + V_S - V_C$. Here, U denotes utility of consuming and η_C costs of using cash. If no trading takes place, the cash trader receives a permanent monetary benefit γ_C. In the case of storage costs and/or

[1]There are some alternatives to model partial acceptance of a currency. For instance, assume two types of sellers, A and B. Seller A always accepts a currency whereas seller B always rejects the currency. The overall acceptance rate depends on the distribution across sellers. This approach may be seen as more intuitive, but needs the assumption of a fourth trading state. Based on some calculations, we conclude that the additional insights do not warrant the additional algebra, we give precedence to simplicity.

inflation, we have $\gamma_C < 0$. For a digital money trader, the line of argument is very much the same, see Eq. (3). A trade between a cash and a digital money trader does not make both agents better off. Since we rule out side-payments (see Aiyagari et al., 1996), money traders continue with their own money.

Our focus will be on symmetric equilibria with $\pi_C(i) = \Pi_C$ and $\pi_D(i) = \Pi_D$. In accordance with Kiyotaki and Wright (1993), welfare is defined by the expected utility of all agents before the initial endowment of money and commodities is randomly distributed among them. In terms of expected flow returns, the welfare criterion can be expressed as:

$$rW = \mu_S rV_S + \mu_C rV_C + \mu_D rV_D. \tag{4}$$

3 Single Currency Regime

It is a truism that the welfare effect of a new currency very much depends on the starting point (or initial equilibrium). Since we are primarily interested in developed economies with a wellfunctioning payment system, our starting point will be a single currency regime, only cash is in circulation, and cash is fully accepted.

In the initial equilibrium, there is no digital money, $\mu_D = 0$. Full acceptance of cash, $\pi_C(i) = \Pi_C = 1$, requires that the gain of accepting cash and switching the state from S to C must be positive, $V_C - V_S > 0$. For the single currency regime, the Bellman equations simplify to

$$rV_S = \mu_C(V_C - V_S) \tag{5}$$

$$rV_C = \gamma_C + \mu_S(U - \eta_C + V_S - V_C). \tag{6}$$

By combining these equations it is easy to show that the condition $V_C - V_S > 0$ is equivalent to

$$\rho_C \equiv \gamma_C + \mu_S(U - \eta_C) > 0. \tag{7}$$

Here, ρ_C is the expected per period return of cash. If the sum of the expected net utility from buying and consuming a good minus the storage costs (or plus the monetary benefit) is positive, cash will be universally accepted.

Inserting (5) and (6) into (4), and observing $\mu_D = 0$, delivers the level of welfare in the single currency regime:

$$rW = \mu_C \rho_C. \tag{8}$$

Notice that the welfare effects of switching the status add up to zero. Sellers improve their welfare by switching the status from S to C, but the cash traders face an equal-sized expected loss of switching from C to S.

An increase in the money supply, in our model captured by an increase in the fraction of cash traders, has two (well-known) effects on welfare. A higher μ_C facilitates trade, sellers find a trading partner more easily (liquidity effect). But a higher μ_C means a lower μ_S, the number of commodities (sellers) declines. The welfare-maximizing fraction of cash traders, μ_C^*, balances these effects. Observing (7) as well as $\mu_S = 1 - \mu_C$, the derivation of (8) with respect to μ_C yields

$$\mu_C^* = \frac{1}{2} + \frac{\gamma_C}{2(U - \eta_C)}. \tag{9}$$

Eq. (9) extends Kiyotaki and Wright (1993), who focus on the special case $\gamma_C = 0$ with $\mu_C^* = 1/2$. Depending on the sign of γ_C (monetary benefit versus storage costs), μ_C^* exceeds or falls short of 1/2.

4 Two switching scenarios

Besides the initial equilibrium, the welfare effect also depends on the acceptance of the new currency. We distinguish between two scenarios. First, cash is fully accepted and the digital currency is partially accepted (Section 4.1), and second, both currencies are fully accepted (Section 4.2)[2].

4.1 Cash Fully Accepted, Digital Money Partially Accepted

The introduction of a new currency means that digital money is part of the initial endowment, $\mu_D > 0$. As mentioned above, partial acceptance of digital money requires that sellers are indifferent between state S and state D, $V_S = V_D$. Sellers flip a coin with $\pi_D(i) = \Pi_D < 1$. Denoting partial acceptance of digital money with the superscript p, the Bellman equations are now:

$$rV_S^p = \mu_C^p(V_C^p - V_S^p) \tag{10}$$

$$rV_C^p = \gamma_C + \mu_S^p(U - \eta_C + V_S^p - V_C^p) \tag{11}$$

$$rV_D^p = \gamma_D + \mu_S^p \Pi_D(U - \eta_D). \tag{12}$$

Any comparative statics analysis needs a hypothesis on the replacement of sellers and cash traders by the digital money traders. This is done by

$$\mu_S^p = \mu_S - \lambda\mu_d \tag{13}$$

[2]We do not model the way to becoming a cashless society. Cash will maintain the status of legal tender, and, even more important, central banks will not be powerless witnesses of the decline in the demand for their product. We agree with Rogoff (2017): "..., it is hard to see what would stop central banks from creating their own digital currencies and using regulation to tilt the playing field until they win. The long history of currency tells us that what the private sector innovates, the state eventually regulates and appropriates." An interesting case study is Sweden, where the usage of cash dramatically declined. But the decline is not the result of cryptocurrencies or corporate currencies, but primarily the result of the app "Swish", which allows for payments avoiding the central bank clearing system (see Sveriges Riksbank, 2021).

$$\mu_C^d = \mu_C - (1-\lambda)\mu_D, \tag{14}$$

where $\lambda \in [0,1]$ denotes the replacement parameter. For $\lambda = 0$, digital money traders do not replace any seller, the economy's endowment with goods remains the same, the digital money traders replace one-to-one cash traders. The new currency does not change the endowment of the economy with money, but the money supply is now made up of two fiat currencies.

For $\lambda = 1$, digital money traders replace only sellers. Since the proportion of cash traders remains constant, the new currency implies an increase in the economy's money supply. The replacement parameter serves as a measure of the degree of substitution between digital money and cash. For low values ($\lambda < 1/2$), digital money and cash are close substitutes, whereas for large values ($\lambda > 1/2$), these currencies are bad substitutes.

The equilibrium acceptance rate turns out to be

$$\Pi_D = \frac{\mu_C^p \nu_C^p \rho_C^p - \gamma_D}{\mu_S^p (U - \eta_D)} \tag{15}$$

with $\nu_C^p \equiv \frac{1}{1+r-\mu_D}$ and $\rho_C^p \equiv \gamma_C + \mu_S^p(U - \eta_C) > 0$. Note that Π_D is decreasing in the monetary benefit of digital money, γ_D, and increasing in the using costs, η_D. If, for instance, the monetary benefit goes up, digital money will become more attractive, the expected flow return of digital money increases and exceeds the flow return to a seller. To restore indifference between being a seller and a digital money trader requires a lower acceptance rate for digital money. In a similar vein, when the expected per period return of cash, ρ_C^p, increases, the seller's gain of switching from S to C increases, V_S^p exceeds V_D^p. Again, to restore indifference, the equilibrium acceptance rate must be higher.

Let us consider welfare. We use the Bellman equations (10) - (12) to compute the new expected returns to search and insert the results into (4). We yield

$$rW^p = (1 + \mu_D \nu_C^p)\mu_C^p \rho_C^p. \tag{16}$$

The comparison of (16) with (8) starts with the polar case $\lambda = 0$, digital money traders replace only cash traders. Then we can show that $rW^p - rW > 0$ requires $0 > r + \mu_S^p$. This condition is never fulfilled. Therefore, for $\lambda = 0$, the introduction of a new partially accepted currency unambiguously lowers welfare. The cash traders, who are replaced by digital money traders, switch from a currency with full acceptance to a currency with partial acceptance. The aggregate money supply does not change, but the probability of a successful match and thus the liquidity value declines. For $\lambda = 1$, where digital money traders replace only sellers, we get

$$rW^p > rW > 0 \quad \Leftrightarrow \quad \frac{\gamma_C}{r + \mu_C} > U - \eta_C. \tag{17}$$

We distinguish between three effects on welfare. First, the economy is less well endowed with goods. Second, exchange is made easier by the increase in the money supply (liquidity). And third, from the cash traders point of view, the number of trades declines, so that the expected holding period of cash goes up. For $\gamma_C \neq 0$, this matters for welfare.

For $\gamma_C = 0$, condition (17) is not fulfilled, the new currency lowers welfare. Since there is a fully accepted currency already in place, the liquidity effect is positive but small. The negative endowment effect unambiguously dominates. If cash has some storage costs, $\gamma_C < 0$, the prolongation of the holding period amplifies the decline in welfare.

A monetary benefit of the traditional currency and thus a positive prolongation effect, $\gamma_C > 0$, turns out to be a necessary condition for a positive welfare effect of the new currency. Note that the prolongation effect declines in both the discount rate r and the share of cash traders, μ_C. The higher μ_C, the longer the holding period in the initial equilibrium, and the lower is the marginal welfare effect.

The welfare-maximizing fraction of cash traders is also affected by the introduction of a new partially accepted currency. Maximizing (16) with respect to μ_C^p yields

$$(\mu_C^p)^* = \frac{1-\mu_D}{2} + \frac{\gamma_C}{2(U-\eta_C)}. \tag{18}$$

The optimal fraction of cash traders is decreasing in the fraction of digital money traders. The optimal response to an increase in liquidity supplied by digital money traders is a decline in liquidity supplied by the cash traders. Note that this result does not depend on the replacement parameter λ, and thus on the question whether digital money and cash are good or bad substitutes.

The replacement parameter comes into play, if the optimal response to the new currency, given by (18), differs from the actual response assumed in (14). The optimal response to the introduction of digital money is a decline of μ_C^p by $\frac{\mu_D}{2}$, the (assumed) actual response of μ_C^p is a decline by $(1-\lambda)\mu_D$. If digital money and cash are close substitutes ($\lambda < 1/2$), the actual decline exceeds the optimal decline, and to close the gap, it is optimal to increase the cash money supply. On the other hand, if digital money and cash are bad substitutes ($\lambda > 1/2$), the actual decline of μ_C^p falls short of the optimal decline, and now it is optimal to lower the cash money supply. Proposition 1 summarizes.

Proposition 1: *Suppose that cash is fully accepted and the new currency is partially accepted. (i) If digital money and cash are very close substitutes ($\lambda \to 0$), the new currency lowers welfare. (ii) If digital money and cash are very bad substitutes ($\lambda \to 1$), a positive welfare effect requires a "strong" monetary benefit of cash. (iii) A new currency lowers the welfare-maximizing supply of cash. (iv) If the new currency primarily replaces cash (goods), the welfare-maximizing response to the new currency is an increase (a decline) in the cash money supply.*

4.2 Both Currencies Fully Accepted

Our second switching scenario assumes $\Pi_C = \Pi_D = 1$. Full acceptance of cash requires $V_C > V_S$, full acceptance of the digital money requires $V_D > V_S$. Rearranging the Bellman equations (1) to (3) shows that these constraints are fulfilled if and only if

$$\rho_C^f > \mu_D \nu_D^f \rho_D^f \quad \Leftrightarrow \quad V_C^f > V_S^f \tag{19}$$

$$\rho_D^f > \mu_C^f \nu_C^f \rho_C^f \quad \Leftrightarrow \quad V_D^f > V_S^f \tag{20}$$

hold. Here, $\rho_D^f \equiv \gamma_D + \mu_S^f(U - \eta_D)$ is the expected per period return of the digital currency, and $\nu_D^f \equiv \frac{1}{r+\mu_S^f+\mu_D}$. The superscript f denotes the dual currency regime with full acceptance of the new currency. If the expected per period return of cash does not exceed threshold (19), cash will not be longer fully accepted. Similarly, if the expected per period return of the digital money does not exceed threshold (20), the digital money will not be fully accepted. To put it different, the spread between ρ_D^f and ρ_C^f, given by $\rho_D^f - \rho_C^f = \gamma_D - \gamma_C - \mu_S^f(\eta_D - \eta_C)$, must not be too big, otherwise either the digital currency or cash is no longer fully accepted.

Welfare in the regime of two fully accepted currencies can be computed as

$$rW^f = \mu_C^f \rho_C^f + \mu_D \rho_D^f. \tag{21}$$

To sign the net welfare effect of the introduction of a universally accepted new currency, we have to compare (21) with (8). Again, we need a hypothesis on the replacement of sellers and cash traders by the digital money traders. We adapt (13) and (14) by assuming $\mu_S^f = \mu_S - \lambda\mu_D$ and $\mu_C^f = \mu_C - (1-\lambda)\mu_D$. With these expressions at hand, the condition for a positive net welfare effect can be written as

$$rW^f > rW \quad \Leftrightarrow \quad -\Gamma_1\lambda^2 + \Gamma_2\lambda + \Gamma_3 > 0 \tag{22}$$

with $\Gamma_1 \equiv \mu_D(U - \eta_C)$ and $\Gamma_2 \equiv \gamma_C + (\mu_D + \mu_S - \mu_C)(U - \eta_C) - \mu_D(U - \eta_D)$ and $\Gamma_3 \equiv \gamma_D + \mu_S(U - \eta_D) - [\gamma_C + \mu_S(U - \eta_C)]$.

Suppose digital money and cash are very close substitutes, so that digital money traders replace only cash traders, whereas the number of sellers remains constant, $\lambda = 0$. In this case, (22) boils down to $\Gamma_3 > 0$. The cash traders, who switch status from C to D, switch to a currency with the same liquidity value (acceptance rate), they gain $\gamma_D + \mu_S(U - \eta_D)$, they lose $\gamma_C + \mu_S(U - \eta_C)$. If the former exceeds the latter, the economy yields a payoff.

If digital money and cash are bad substitutes, digital traders replace only sellers, $\lambda = 1$. Condition (22) simplifies to $\rho_D^f > \mu_C(U - \eta_C)$. The sellers, who switch status from S to D, gain ρ_D^f . But the cash traders face a loss. Since there is a lower number of sellers, the probability of exchange and consumption declines.

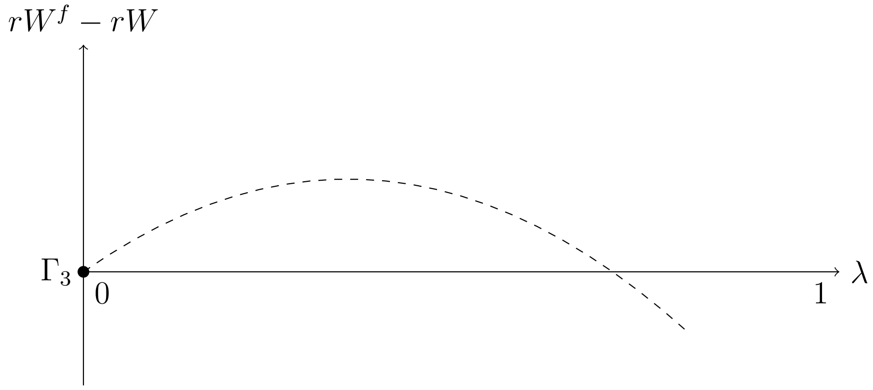

Figure 1: Solution to $rW^f - rW > 0$

Net welfare is a quadratic function in λ. Depending on λ, the sign of the net welfare effect may change. Figure 1 illustrates this, we assume $\Gamma_3 = 0$. For $\lambda = 0$, the new currency is neutral with respect to welfare. As λ increases, so does the sum of cash and digital money (aggregate money supply). Therefore, an increase in λ very much resembles an increase in money supply in the Kiyotaki-Wright (1993) framework. Endowing more agents with money facilitates exchange and improves welfare, the net welfare effect becomes positive. But endowing more agents with money is equivalent to endowing fewer agents with commodities, consumption and welfare go down. If the replacement parameter λ exceeds a critical value λ_{crit} with $\lambda_{crit} = \Gamma_2/\Gamma_1$, the net welfare effect switches the sign and turns into negative. Two remarks are in order. First, the higher the fraction of cash traders in the initial equilibrium, μ_C, the lower is the welfare-enhancing liquidity effect of a new currency, and the more important is the negative effect of the lower number of commodities, λ_{crit} declines, the probability of a negative net welfare goes up. Second, λ_{crit} may be larger than one. In this case, we observe a net welfare gain for all $\lambda \in (0, 1]$. The welfare effects of a relaxation of the assumption $\Gamma_3 = 0$ are straightforward, in Figure 1 the net welfare curve shifts up ($\Gamma_3 > 0$) or down ($\Gamma_3 < 0$). Since there are no novel and crucial insights, we skip the discussion.

In a world with two fully accepted currencies, the welfare-maximizing fraction of cash traders is given by:

$$\left(\mu_C^f\right)^* = \frac{1-\mu_D}{2} + \frac{\gamma_C}{2(U-\eta_C)} - \frac{\mu_D(U-\eta_D)}{2(U-\eta_C)} = (\mu_C^p)^* - \frac{\mu_D(U-\eta_D)}{2(U-\eta_C)}. \quad (23)$$

As shown above, the optimal response to the introduction of a partially accepted currency is a decline in the supply of cash (fraction of cash traders) by $\frac{\mu_D}{2}$. If instead the new currency is fully accepted, its liquidity value is even higher, so that the decline in the optimal supply of cash is even stronger. We get

Proposition 2: *Suppose that both cash and the new currency are fully accepted. (i) The existence of an equilibrium requires that the spread $\rho_D^f - \rho_C^f$ must not be too big. (ii) If digital money and cash are very close substitutes ($\lambda \to 0$), a positive spread ensures a net welfare gain. (iii) The lower the degree of substitution between digital money and cash (increasing λ), the higher the probability of a negative net welfare effect. (iv) A new fully accepted currency lowers the welfare-maximizing supply of cash more than the introduction of a partially accepted currency.*

5 Conclusion

Digital currencies are on the rise. Our analysis provides insight into the welfare effects of this development. Using an economy with a fully accepted currency as benchmark, we identify the conditions under which the introduction of a secondary (digital) currency improves welfare. A decisive factor turns out to be the degree of substitution between the new currency and cash, this factor determines how many agents switch from an endowment with cash to an endowment with digital money.

Our results may serve as a helping hand for the government to the question how to regulate a new currency. Of course, our framework is too simple to draw far-reaching policy conclusions, extensions are necessary. However, we are at the starting point of a fruitful discussion of the economic consequences of digital currencies. Two promising lines of research are the impact on financial intermediation, for an overview see Thakor (2020), and the macroeconomic consequences of a central bank digital currency (see, e.g., Barrdear and Kumhof, 2021, and Fegatelli, 2022).

Acknowledgements

We gratefully acknowledge helpful comments from Mario Gomez, Andreas Hanl, Jan Hattenbach, Simon Hildebrandt, Luzie Thiel, Rainer Voßkamp, and, in particular, Georg von Wangenheim. Fuchs acknowledges the financial support by a graduate scholarship of the University of Kassel.

References

Airaudo, Marco (2014): "Currency substitution, risk premia and the Taylor principle", *Journal of Economic Dynamics and Control* 48: 202-217.

Barrdear, John and Michael Kumhof (2021): "The macroeconomics of central bank digital currencies", *Journal of Economic Dynamics and Control*, Article 104148, forthcoming.

Calvo, Guillermo and Carlos Végh (1992): "Currency substitution in developing countries: an introduction", *Revista de Analisis Economico* 7(1): 3-27.

Camera, Gabriele, Ben Craig and Christopher Waller (2004): "Currency competition in a fundamental model of money", *Journal of International Economics*

64(2): 521-544.

Colacelli, Mariana and David Blackburn (2009): "Secondary currency: An empirical analysis", *Journal of Monetary Economics* 56(3): 295-308.

Ding, Shuze and Daniela Puzello (2020): "Legal Restrictions and International Currencies: An Experimental Approach", *Journal of International Economics* 126 (September), Article 103342.

Fegatelli, Paolo (2022): "A central bank digital currency in a heterogeneous monetary union: Managing the effects on the bank lending channel", *Journal of Macroeconomics* 71, March, Article 103392.

Giovannini, Alberto and Bart Turtelboom (1994): "Currency Substitution", in: F. van der Ploeg (ed.), *Handbook of International Macroeconomics*, Cambridge MA, pp. 390-436.

Lippi, Francesco (2021): "The Fiscal Arithmetic of a Dual Currency Regime", *Journal of Money, Credit and Banking* 53(7): 1887-1897.

Rogoff, Kenneth (2017): "Crypto Fool's Gold?", Project Syndicate, October 9, 2017, https://www.project-syndicate.org/commentary/bitcoin-long-term-price-collapse-by-kennethrogoff- 2017-10.

Schillig, Linda and Harald Uhlig (2019): "Some simple bitcoin economics", *Journal of Monetary Economics* 106: 16-26.

Selcuk, Faruk (2003): "Currency substitution: new evidence from emerging markets", *Economics Letters* 78(2): 219-224.

Sveriges Riksbank (2021): Payments Report, Stockholm.

Thakor, Anjan (2020): "Fintech and banking: What do we know?", *Journal of Financial Intermediation* 41, January, Article 100833.

Uhlig, Harald and Taojun Xie (2020): Parallel Digital Currencies and Sticky Prices, NBER Working Paper No. 28300, Cambridge MA.