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Consumption Loan Augmented Divisia Monetary Index and China Monetary Aggregation

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Abstract: Simple sum monetary aggregates are based on accounting conventions and have no aggregation theoretic foundations in economic theory. In contrast, Divisia monetary aggregates are directly derived from aggregation and index number theory. Credit card services cannot be included in simple sum monetary aggregates since accounting conventions cannot aggregate over assets and liabilities. However, microeconomic aggregation theory aggregates over service flows, not stocks, regardless of whether from assets or liabilities. As a result, it has recently been shown that Divisia monetary aggregates can be augmented to include credit card services and are available from the Center for Financial Stability in New York City. Other sources of consumer credit cannot be included in Divisia monetary aggregates for the United States since other sources of consumer credit in the United States are linked to specific groups of consumer goods and hence, violate the weak separability condition for the existence of an aggregator function. However, China produces a unique opportunity to broaden the Divisia monetary aggregates since sources of consumer credit, not limited to credit cards, are applicable to all consumption purchases and hence, do not violate the existence condition for an aggregator function. We report initial results with a broader Chinese Divisia monetary aggregate, including not only credit card services but also other broadly acceptable consumer loan services.

Keywords: Divisia monetary aggregates; consumption loans; Chinese monetary aggregates

JEL Classification: C32; C53; E31; E47; E51

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1. Introduction

During the COVID-19 pandemic, many retailers closed physical stores, while online customers increased. The James Eyers (2020) commented that Afterpay, a buy-now-pay-later service provider, was growing rapidly: "Investors are seeking exposure to e-commerce as the coronavirus crisis pushes more shopping online, and continuing government stimulus will keep bad debts low." Meantime, E-commerce consumption loan services have moved to their next stage in China. In October 2020, Ant Group, the world's largest mobile, and online payments platform and provider of e-commerce consumption loan Ant Check Later, was set to raise US$34.5 billion in the world's largest IPO at the time, valuing the company at US$313 billion (Xie et al. 2020).

Studies on e-commerce consumption loan services have found that millennials are their main customer demographic, accounting for 75% of all users (Boyd 2019). Another significant segment of e-commerce consumption loan customer base is university students, of whom one-third have been found to use short-term borrowing (West and Cull 2020). With the booming of electronic business, which started during the last decade, e-commerce consumption loans include the hottest buy-now-pay-later services provided by non-banking financial institutions. Those services are playing a more important role than ever.

However, as a new form of transaction service, its measurement and inclusion in monetary aggregation need to be derived from aggregation theory. Unlike mortgage loans, consumption loans do not require real estate as a guaranty. Moreover, the services of consumption loans are not the same as the services of bank-issued credit card transactions. With their independent credit evaluation system and limited liquidity in markets, consumption loans in e-commerce provide unique services that need to be evaluated on their own in monetary aggregation.

Barnett (1980) originated the well-known Divisia monetary aggregates to aggregate over the services of monetary assets. Barnett et al. (2016) extended those aggregates to include the monetary services of some liabilities, namely credit cards, which provide deferred payment transaction services. Based on the microeconomic theory of aggregation and the results for liabilities in aggregation, we find that it is possible to measure the services of non-banking consumption loans in e-commerce on the demand side and thereby to further expand upon the scope of the Divisia monetary aggregates.

To be able to measure the joint services of e-commerce consumption loans and money, an existence condition in aggregation theory must be satisfied. That condition is blockwise weak separability of the components of the aggregate from other variables in consumer utility functions. A relevant payment service must be able to pay for all consumer goods and services in the utility function to satisfy the weak separability condition. Otherwise, the services of the asset or liability are linked to a subset of consumer goods and hence cannot be within a weakly separable block of services in the utility function. More details of that important existence condition will be discussed in the following models.

Huabei consumption loan services that rely on the world's largest mobile and online payments platform, Alipay, have already been applied to all consumption in China, including groceries and utilities, while e-commerce consumption loans in other countries remain limited to fashion retailers or designer brands.[1] In this paper, we use the volume of Huabei services as the empirical data source and update the results for China's monetary aggregation. While the weak separability condition is satisfied for China now, we expect that in the future, the condition will be satisfied in other countries as the scope of payment for consumer loans expands.

The most recent research on China's Divisia Monetary Aggregation was published in 2016 by Barnett and Tang (2016). In late 2015, China completed its process of interest rate marketization. Updated monetary aggregation may provide more information about China's interest rate marketization process. Moreover, a longer data horizon would provide more information in frequency domain analysis (Oppenheim et al. 1999). By applying spectral analysis to China's monetary aggregates, our results show that in the short run, coherencies between monetary aggregates and nominal GDP decline. There are lags between monetary aggregate changes and nominal GDP changes. These results are consistent with Milton Friedman's conclusion that targeting the quantity of money in the short run is defective (Friedman 1996). Long-run monetary aggregates should be taken seriously, as we show for our extended Divisia monetary aggregates for China.

2. The Model

Assume that the resource allocation of the representative consumer focuses on three types of variables in the utility function: Consumption of goods and services, monetary services (including both assets and liabilities providing those services), and the benchmark asset, represented by A_s. The benchmark asset refers to investment in pure capital providing no liquidity or services other than the expected investment return. By definition, the benchmark asset provides no monetary services.

2.1. Consumer's Utility Maximization Problem

Let period t be the current period, closed on the left and open on the right, so all transactions take place at the instant at the beginning of the period. The current and

next periods are periods $s \in \{t, t+1\}$. First, we define the variables that are used in the consumer's utility maximization problem:

$\mathbf{c}_s$ = vector of per capita (planned) consumptions of goods and services (including those of durables) during period s.
$\mathbf{p}_s$ = vector of goods and services expected prices and of durable goods expected rental prices during period s.
p_s^* = true cost of living index, used to deflate nominal to real values.
m_{is} = planned per capita real balance of monetary asset i during period s $(i = 1, \ldots, n)$.
r_{is} = the expected nominal holding period yield (including capital gains and losses) on monetary asset i $(i = 1, \ldots, n)$ during period s.
d_{js} = real expenditure volumes with consumption loan type j (including credit card services) for transactions during period s $(j = 1, \ldots, k)$.
e_{js} = expected interest rate on consumption loan d_{js} during period s for $j = 1, \ldots, k$.
A_s = planned per capita real benchmark asset holding during period s.
R_s = the expected (one-period holding period) yield on the benchmark asset during period s. L_s = per capita labor supply during period s.
W_s = the wage rate during period s.

Then the consumer's intertemporal two-period decision problem is to choose $(\mathbf{c}_t, \mathbf{c}_{t+1}; \mathbf{d}_t, \mathbf{d}_{t+1}; \mathbf{m}_t, \mathbf{m}_{t+1}; A_{t+1})$ at time t to

$$\max u(\mathbf{c}_t, \mathbf{c}_{t+1}; \mathbf{d}_t, \mathbf{d}_{t+1}; \mathbf{m}_t, \mathbf{m}_{t+1}; A_{t+1}) \tag{1}$$

subject to

$$\mathbf{p}_t\mathbf{c}_t = W_tL_t + p_t^*\mathbf{d}_t - (1+\mathbf{e}_{t-1})p_{t-1}^*\mathbf{d}_{t-1} + (1+\mathbf{r}_{t-1})p_{t-1}^*\mathbf{m}_{t-1} - p_t^*\mathbf{m}_t + (1+R_{t-1})p_{t-1}^*A_{t-1} - p_t^*A_t \tag{2}$$

Here, only the benchmark asset of the second period will appear in the utility function since the benchmark asset is defined as not providing monetary services. The role of the benchmark asset in other periods is only for intertemporal wealth transfer. The existence of the conditional two-period decision implicitly assumes weak separability of the two periods from future periods. We make that assumption solely for expositional simplicity. The generalization to a T period or infinite period planning horizon is straightforward, as shown in the original derivations of the Divisia monetary aggregates by Barnett (1980), as well as Serletis and Gogas (2014).

2.2. User Cost of Consumption Loans

The Lagrangian function is

$$\begin{aligned} L = {} & u(\mathbf{c}_t, \mathbf{c}_{t+1}; \mathbf{d}_t, \mathbf{d}_{t+1}; \mathbf{m}_t, \mathbf{m}_{t+1}; A_{t+1}) \\ & + \lambda_0[W_tL_t + p_t^*\mathbf{d}_t - (1+\mathbf{e}_{t-1})p_{t-1}^*\mathbf{d}_{t-1} + (1+\mathbf{r}_{t-1})p_{t-1}^*\mathbf{m}_{t-1} - p_t^*\mathbf{m}_t + (1+R_{t-1})p_{t-1}^*A_{t-1} - p_t^*A_t - \mathbf{p}_t\mathbf{c}_t] \\ & + \lambda_1[W_{t+1}L_{t+1} + p_{t+1}^*\mathbf{d}_{t+1} - (1+\mathbf{e}_t)p_t^*\mathbf{d}_t + (1+\mathbf{r}_t)p_t^*\mathbf{m}_t - p_{t+1}^*\mathbf{m}_{t+1} + (1+R_t)p_t^*A_t - p_{t+1}^*A_{t+1} - \mathbf{p}_{t+1}\mathbf{c}_{t+1}]. \end{aligned} \tag{3}$$

The first order conditions are

$$\frac{\partial L}{\partial \mathbf{c}_t} = \frac{\partial u}{\partial \mathbf{c}_t} - \lambda_0\mathbf{p}_t = 0 \tag{4}$$

$$\frac{\partial L}{\partial \mathbf{m}_t} = \frac{\partial u}{\partial \mathbf{m}_t} - \lambda_0 p_t^* + \lambda_1(1+\mathbf{r}_t)p_t^* = 0 \tag{5}$$

$$\frac{\partial L}{\partial \mathbf{d}_t} = \frac{\partial u}{\partial \mathbf{d}_t} + \lambda_0 p_t^* - \lambda_1(1+\mathbf{e}_t)p_t^* = 0 \tag{6}$$

$$\frac{\partial L}{\partial A_t} = \frac{\partial u}{\partial A_t} - \lambda_0 p_t^* + \lambda_1(1+R_t)p_t^* = 0 \tag{7}$$

From Equations (4)–(7), we have

$$\frac{\partial u}{\partial \mathbf{c}_t} = \lambda_0 \mathbf{p}_t \tag{8}$$

$$\frac{\partial u}{\partial \mathbf{m}_t} = \lambda_0 p_t^* - \lambda_1 (1 + \mathbf{r}_t) p_t^* \tag{9}$$

$$\frac{\partial u}{\partial \mathbf{d}_t} = -\lambda_0 p_t^* + \lambda_1 (1 + \mathbf{e}_t) p_t^* \tag{10}$$

$$\frac{\partial u}{\partial A_t} = \lambda_0 p_t^* - \lambda_1 (1 + R_t) p_t^* \tag{11}$$

Since the benchmark asset provides no marginal utility services during the planning horizon and serves solely to transfer wealth to the next planning horizon, it follows that $\frac{\partial u}{\partial A_t} = 0$. Hence,

$$\lambda_1 = \frac{\lambda_0}{1 + R_t} \tag{12}$$

Substitute (12) into (9) and (10), we have

$$\frac{\partial u}{\partial \mathbf{m}_t} = \lambda_0 p_t^* \frac{R_t - \mathbf{r}_t}{1 + R_t} \tag{13}$$

$$\frac{\partial u}{\partial \mathbf{d}_t} = \lambda_0 p_t^* \frac{\mathbf{e}_t - R_t}{1 + R_t} \tag{14}$$

Note that when $\lambda_0 = 1$, the marginal utility of current consumption is the price of consumer goods. As we assume that monetary assets and credit cards produce durable services, their rental prices or user cost prices are just the marginal utilities in our model:

$$\pi_{it} = \frac{p_t^* (R_t - r_{it})}{1 + R_t} \tag{15}$$

$$\widetilde{\pi}_{jt} = \frac{p_t^* (e_{jt} - R_t)}{1 + R_t} \tag{16}$$

Here π_{it} is the nominal user cost price of monetary asset i at time t, where $\boldsymbol{\pi}_\mathbf{t} = (\pi_{1t}, \pi_{2t}, \ldots, \pi_{nt})'$, which is the nominal user cost vector of monetary assets in period t; while $\widetilde{\pi}_{jt}$ is the nominal use cost of consumption loans type j, where $\widetilde{\boldsymbol{\pi}}_\mathbf{t} = (\widetilde{\pi}_{1t}, \widetilde{\pi}_{2t}, \ldots, \widetilde{\pi}_{kt})'$ is the nominal user cost vector of consumption loans.

2.3. Consumption Loan Augmented Monetary Aggregation

We assume that $(\mathbf{d}_t, \mathbf{m}_t)$ is weakly separable within the utility function $u(\mathbf{c}_t, \mathbf{c}_{t+1}; \mathbf{d}_t, \mathbf{d}_{t+1}; \mathbf{m}_t, \mathbf{m}_{t+1}; A_{t+1})$, so that a quantity aggregator function exists over $(\mathbf{d}_t, \mathbf{m}_t)$.

To ensure the applicability of weak separability, the consumption loans we adopt here should not be limited to specific stores or specific goods purchases. For example, gift cards that are only good for gasoline purchases or one store's goods or e-commerce consumption loan services that are available only for limited retailers would not satisfy the assumption of weak separability. Weak separability allows consumption loans to aggregate along with other payment mechanisms to buy any of the goods in the vector of consumer goods in the utility function.

Let $(\mathbf{m}_\mathbf{t}^*, \mathbf{d}_\mathbf{t}^*) = (m_{1t}, m_{2t}, \ldots, m_{nt}, d_{1t}, d_{2t}, \ldots, d_{kt})'$. In accordance with Barnett (1980), we have that $(\mathbf{m}_\mathbf{t}^*, \mathbf{d}_\mathbf{t}^*)$ is also the solution for the current period conditional decision problem

$$\max u(\mathbf{m}_t, \mathbf{d}_t) \tag{17}$$

subject to

$$\boldsymbol{\pi}_t \cdot \mathbf{m}_t + \widetilde{\boldsymbol{\pi}}_t \cdot \mathbf{d}_t = y_t \tag{18}$$

where $y_t = \boldsymbol{\pi}_t \cdot \mathbf{m}_t + \widetilde{\boldsymbol{\pi}}_t \cdot \mathbf{d}_t$ is the total expenditure on the portfolio of n + k monetary assets and debt basis consumption loans.

If we were further to assume that monetary assets are weakly separable within utility, there would exist an aggregator function over monetary liquid assets $v()$, such that the exact monetary aggregate, M_t, would be $M_t = v(\mathbf{m}_t^*)$. Index theory provides nonparametric tracking of the unknown equation $v()$. In continuous time, the new payment services augmented monetary aggregator, $M_t^c = u(\mathbf{m}_t^*, \mathbf{d}_t^*)$, can be exactly tracked nonparametrically by the Divisia index and is also the solution of the following differential equation,

$$\frac{d \log M_t^c}{dt} = \sum_{i=1}^{n} \omega_{it} \frac{d \log m_{it}^*}{dt} + \sum_{j=1}^{k} \widetilde{\omega}_{jt} \frac{d \log d_{jt}^*}{dt} \tag{19}$$

Here,

$$\omega_{it} = \frac{\pi_{it} m_{it}}{\boldsymbol{\pi}_t \cdot \mathbf{m}_t + \widetilde{\boldsymbol{\pi}}_t \cdot \mathbf{d}_t} = \frac{\pi_{it} m_{it}}{\sum\limits_{i=1}^{n} \pi_{it} m_{it} + \sum\limits_{j=1}^{k} \widetilde{\pi}_{jt} d_{jt}} \tag{20}$$

$$\widetilde{\omega}_{jt} = \frac{\widetilde{\pi}_{jt} d_{jt}}{\boldsymbol{\pi}_t \cdot \mathbf{m}_t + \widetilde{\boldsymbol{\pi}}_t \cdot \mathbf{d}_t} = \frac{\widetilde{\pi}_{jt} d_{jt}}{\sum\limits_{i=1}^{n} \pi_{it} m_{it} + \sum\limits_{j=1}^{k} \widetilde{\pi}_{jt} d_{jt}} \tag{21}$$

The growth rate weight, ω_{it}, is the share of monetary assets in the total consumption of the monetary liquid asset portfolio, and $\widetilde{\omega}_{jt}$ is the share of new payment services such as credit card services or other small consumption loans in the total consumption of the monetary liquid asset portfolio. Since economic data are mostly discrete-time data, it is necessary to perform a second-order Törnqvist-Theil approximation to the above-mentioned continuous-time index. The result is the discrete-time Divisia Index of monetary services:

$$\log M_t^c - \log M_{t-1}^c = \sum_{i=1}^{n} \overline{\omega}_{it} (\log m_{it} - \log m_{i,t-1}) + \sum_{j=1}^{k} \overline{\widetilde{\omega}}_{jt} (\log d_{jt} - \log d_{j,t-1}) \tag{22}$$

where the discrete weights are approximated by

$$\overline{\omega}_{it} = \frac{1}{2}(\omega_{it} + \omega_{i,t-1}) \tag{23}$$

$$\overline{\widetilde{\omega}}_{it} = \frac{1}{2}(\widetilde{\omega}_{jt} + \widetilde{\omega}_{j,t-1}) \tag{24}$$

3. China's Monetary Aggregation

3.1. Data Description and Pretreatments

We detail the sources of our data in this section[2]:

Currency: From January 2000 to December 2020, M0 data provided by PBC.

Demand deposits: From January 2000 to December 2020, provided by PBC.

Fixed deposits: Data only available for all fixed deposits without their maturities. Missing data for September 2001 and November 2001 were estimated by the Linear Interpolation method. The interest rate data use the one-year time deposit interest rate.

Savings deposit: From January 2000 to December 2020. The interest rate data use the one-year time deposit interest rate.

Interbank Lending: From January 2000 to December 2020. Missing data for February 2000 were estimated by the Linear Interpolation method.

Benchmark rate: LPR (Loan Prime Rate), from January 2000 to December 2020, provided by PBC.

GDP: The quarterly GDP data come from the China Statistical Yearbook, from the first quarter of 2000 to the last quarter of 2020. We convert quarterly data into monthly data using

cubic spline interpolation. The monthly approximated GDP with the cubic spline interpolation method is consistent with local monotonicity properties of the data (Hyman 1983).

3.2. Consumption Loan Augmented Divisia Aggregates

We consider the consumption made with credit card services to be a specific type of consumption loan. However, credit card cash withdrawals are not services we are considering. The data available for credit cards is the quarterly volume of credit card services from 2012 to 2020. We use cubic spline interpolation to produce monthly data and perform first order differencing to obtain the monthly added value for credit card loans payable.

The cost of using credit card transaction services in China includes multiple parts. The cost is different from the user cost of credit card services that we considered in the previous sections by the additional fees to be paid by credit card transactions. In addition to the annual fee of the credit card, there is no payment for the consumption on the card. However, when payment is overdue, the bank will charge consumers a repayment penalty of the amount exceeding the minimum repayment amount at an average rate of 5% per month. Since credit card services are settled on a monthly basis, a credit card payable loan will be charged 12 times at most in a year, which annual interest rate would be equivalent to $(1 + 5\%)^{12} - 1 = 0.795856 \approx 79.59\%$.

Based on the average overdue time in China, the average annual interest rate on the outstanding credit card balance is 39.27%.

For e-commerce consumption loans, we adopt data for Huabei service provided by Alibaba China. Alibaba has a 12% share of consumption in China in 2019. That is 2/3 of e-commerce business. Compared with Amazon's Gross Merchandise Volume of 344 billion dollars, Alibaba's is 947 billion dollars in 2018, according to Emarketer's data. Huabei consumption loan services are applicable for all purchases on Alibaba, including not only groceries but also cars, luxuries, and even online courses or other services that are more integrated than on Amazon.

According to the IPO and STAR Market Listing Prospectus released by Ant Alibaba in November 2020, Alipay has more than 1 billion annual active users, and about 500 million use Huabei, of which 33% are "post-90s". "Post-80s" users account for 48.5%, and "70" users account for 48.5%.[3] The "post" user is 14.3%, and its quota is between 500 yuan and 50,000 yuan. In addition to the broad market brought by the population of China and advanced mobile payment platform, lower application requirements are also one of the reasons why it has many users. Any user in mainland China who has passed the real-name system verification and is over 18 years old can apply for Huabei service.

Although Huabei China has attracted more new-generation consumer groups, just like Afterpay Australia, its business scope is broader than buy-now-pay-later services in other countries. It cooperates with nearly 10 million online and offline merchants, covering Life entertainment, business travel, education and training, communication, and leasing industries, and pays Huabei offline through NFC technology, relying on the Alipay payment platform to further expand its usage scenarios and make it available for almost all types of consumption activities.

Being as broadly and fully functional as other monetary assets for consumption purpose, e-commerce consumption loans like Huabei could be considered within the weakly separable block containing monetary assets. All can be used to buy any of the goods in the vector of consumer goods in the utility function.

However, as a new payment service, available data for Huabei and Jiebei are limited from the first quarter of 2017 to the second quarter of 2020. We applied cubic spline interpolation to estimate monthly data. Huabei and Jiebei balances are also payable loan balances, just as credit card balances. The repayment penalty on Huabei payable balances equals the balance times 0.05% per day. With similar methods, we find the average annual interest rate on Huabei payable balances is 14.4%.

Considering the length of the data, we will focus on China's aggregation between Jan 2017 and June 2020. The interest rates of all considered services and monetary assets are summarized in Figure 1, which provides the comparative relations between monetary product return rates and the benchmark rate, ensuring positive user costs of all types of monetary assets and services. The goal is to determine whether consumption loan data could increase information about the macroeconomy.

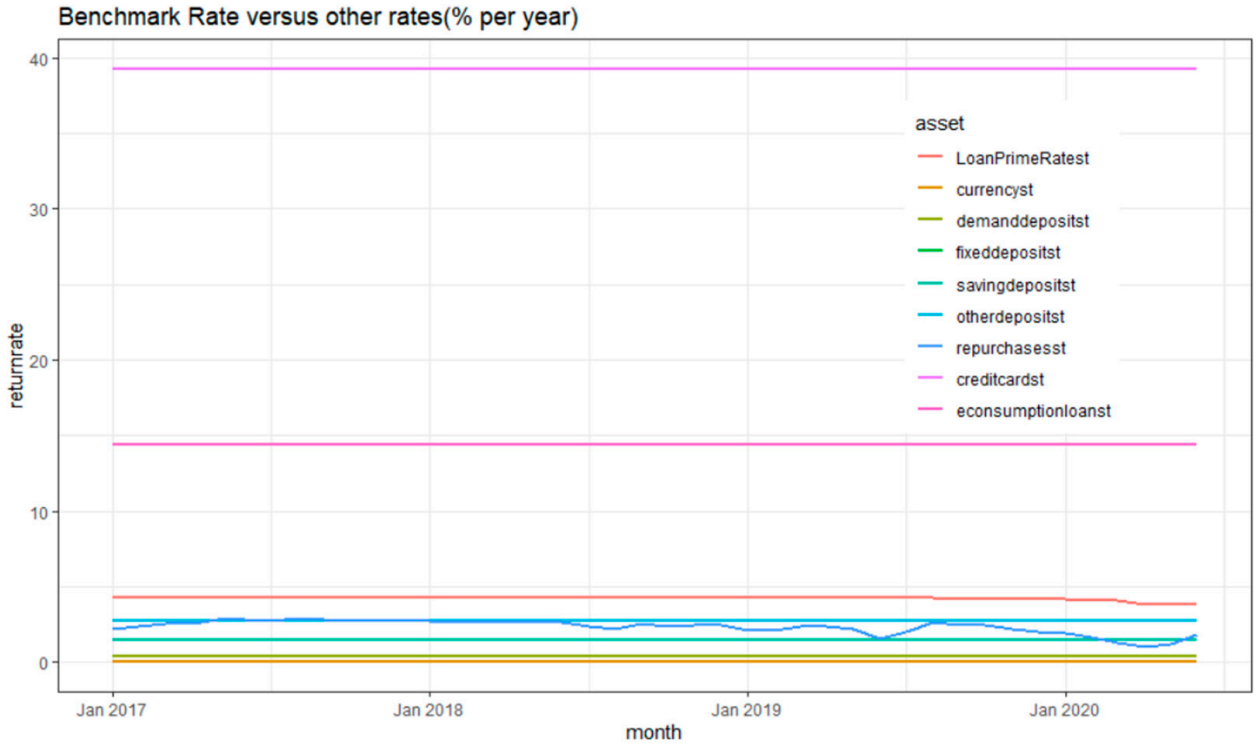

Figure 1. Benchmark rate and other rates (2017–2020).

Based on simple sum monetary aggregation and the published Divisia Monetary Aggregation categorization, the corresponding consumption-loan-augmented monetary aggregates could be categorized by the components in Table 1.

Table 1. Monetary Aggregation Categorization—Table of Components.

Type	M1	DM1	ADM1	M2	DM2	ADM2	M3	DM3	ADM3
Cash	1	1	1	1	1	1	1	1	1
Credit Card Services	0	0	1	0	0	1	0	0	1
(E-commerce) Consumption Loans	0	0	1	0	0	1	0	0	1
Demand Deposits	1	1	1	1	1	1	1	1	1
Fixed Deposits in Commercial Banks	0	0	0	1	1	1	1	1	1
negotiable certificate of deposit	0	0	0	1	0	0	1	1	1
Saving Deposits in Commercial Banks	0	0	0	1	1	1	1	1	1
Fixed Deposits in Finance Companies	0	0	0	0	1	1	1	1	1
Saving Deposits in Finance Companies	0	0	0	0	1	1	1	1	1
Overnight and Term Repurchases	0	0	0	0	0	0	0	1	1
Business Paper and Bills	0	0	0	0	0	0	0	0	0
Treasury Bills	0	0	0	0	0	0	0	0	0

For comparability, we adopt the corresponding simple sum data's initial level for China's Divisia aggregates starting point.

For aggregates over most liquid monetary assets services, our results do not show much difference during most times (see Figure 2). However, aggregates augmented with

consumption loan transaction services show a significant boom after January 2020, precisely at the beginning of the period when the COVID-19 virus broke out (see Figures 3 and 4). During the quarantine period in China, most employees were asked to stay at home and away from their work site. Without a regular income, many people turned to consumption loans, including credit card services and Huabei, to cover their daily expenses and housing mortgage. Only the consumption loan augmented Divisia aggregates show the abnormality caused by the pandemic.

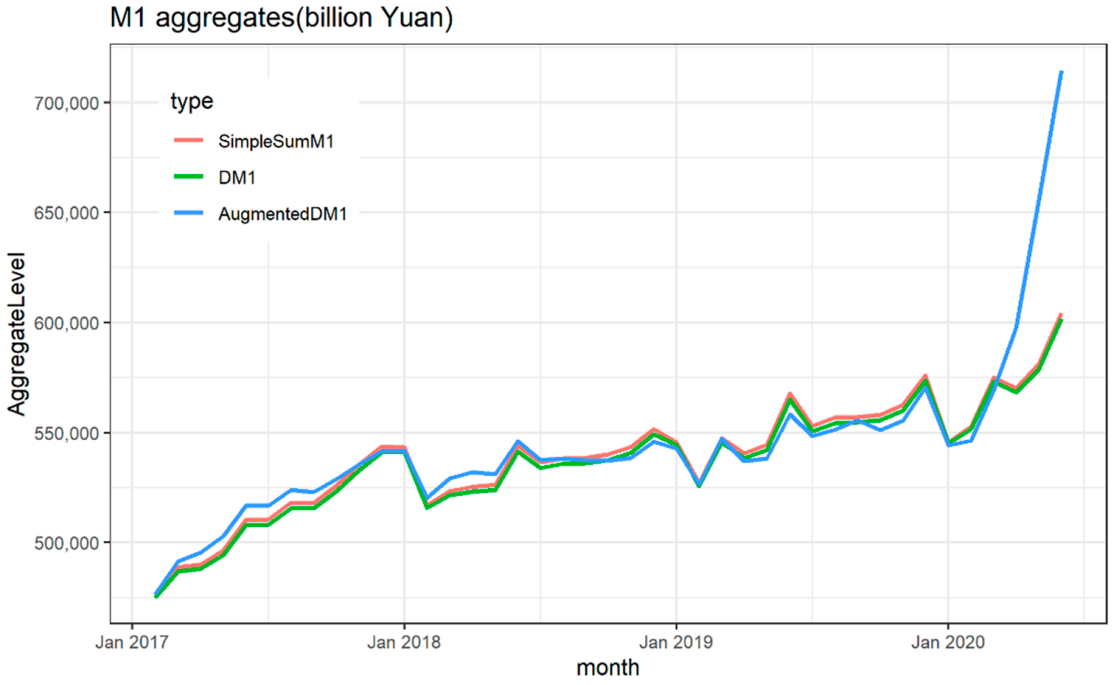

Figure 2. Divisia M1, Consumption Loan Augmented M1 and simple sum M1.

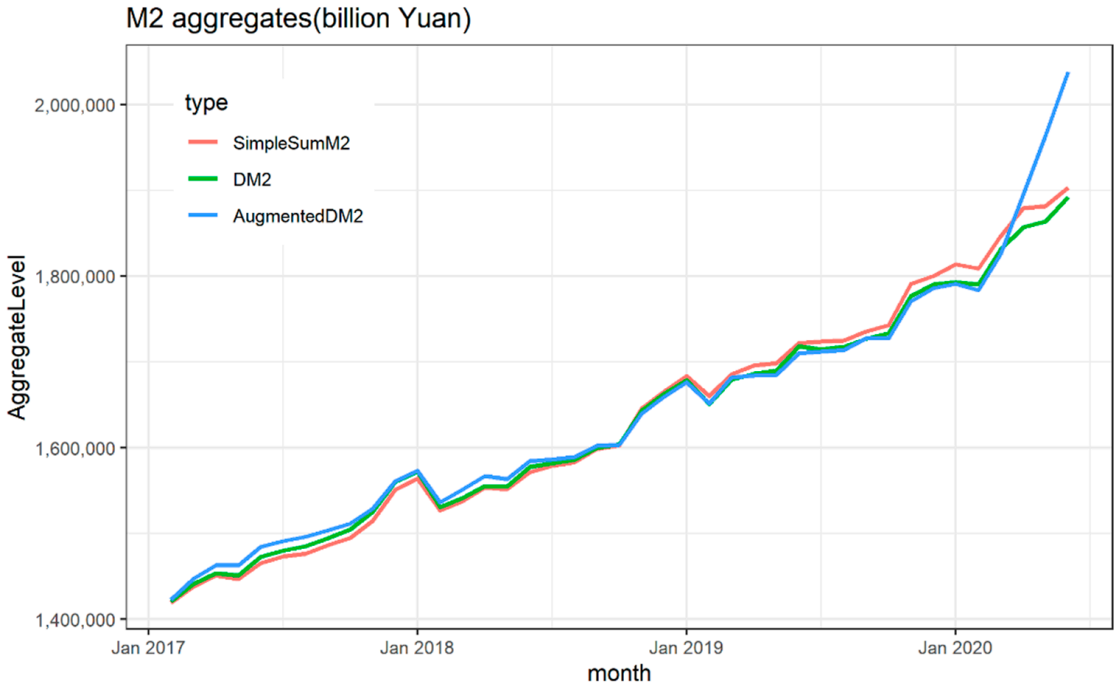

Figure 3. Divisia M2, Consumption Loan Augmented M2 and simple sum M2.

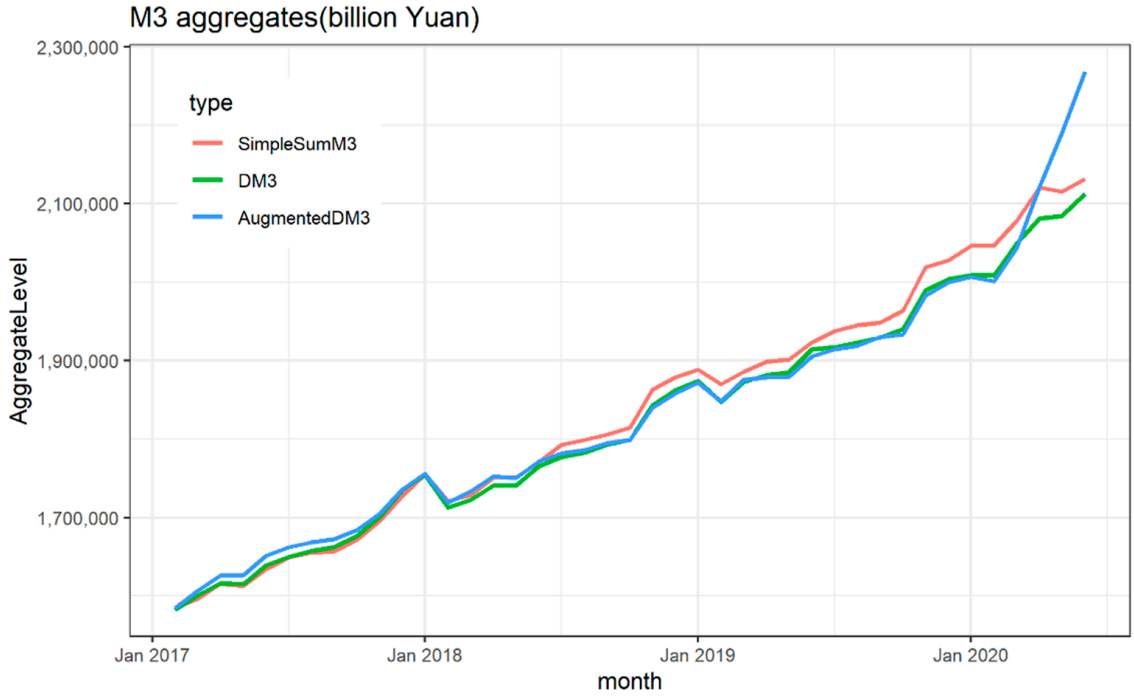

Figure 4. Divisia M3, Consumption Loan Augmented M3 and simple sum M3.

Table 2 shows basic statistics for different consumption loan augmented monetary aggregates. The results show that the difference between Consumption Loan Augmented Divisia monetary aggregation and simple sum aggregation decrease as more monetary assets are included. However, when aggregations get broader, correlation coefficients with monthly GDP decrease. This result is different from related research for money quantity aggregates in other countries. In the following sections, we will compare the results with long-time horizon data and try to explain this anomaly with the spectrum analysis method.

Table 2. Basic statistics for different consumption loan augmented monetary aggregates.

	Min.	Max.	Range	Mean	Std.Dev	Cor(,GDP)
Simple sum M1	476,527.6	604,318	127,790.4	539,213.9	26,187.87	0.7015354
M_1^c	475,117.9	601,579.3	126,464	540,912	26,056.11	0.6933125
M_1^c+	476,410.8	714,589.9	238,179.2	543,895.5	29,402.44	0.7253561
Simple sum M2	1,419,188	1,903,308	484,120	1,633,972	137,898.9	0.5599771
M_2^c	1,420,778	1,892,873	471,094.6	1,631,437	129,664.6	0.5720135
M_2^c+	1,422,516	2,038,599	616,083.3	1,640,332	131,172.1	0.5797076
Simple sum M3	1,584,969	2,131,711	546,744	1,836,080	158,963.4	0.5681474
M_3^c	1,582,517	2,112,359	529,842.6	1,823,183	147,460	0.5759296
M_3^c+	1,584,319	2,268,600	684,270.9	1,832,586	149,378.5	0.5759484

Despite low correlation with nominal GDP, broad Consumption Augmented Divisia Aggregates display obvious advantages over simple sum. Moreover, Divisia aggregates show better stability compared to simple sum aggregates.

3.3. China's Money Supply with Long Time Horizon (Jan 2000–Dec 2020)

By applying Divisia Monetary Aggregation in Section 2, we derive the DM1, DM2, and DM3 for China from January 2000 to December 2020. Figure 5 shows the benchmark rate and other return rates during the long-time horizon.

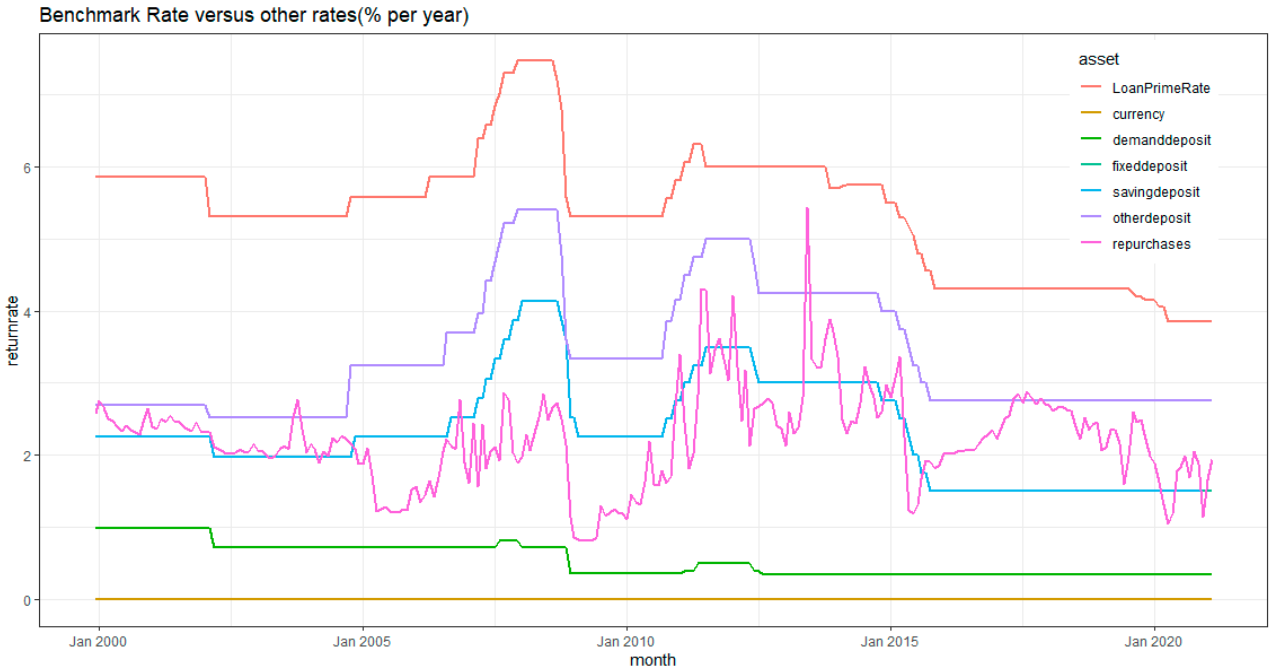

Figure 5. Benchmark rate and other return rates in long time horizon (2000–2020).

Table 3 shows basic statistics for different monetary aggregates. The results show that the difference between Divisia monetary aggregation and simple sum aggregation increases as more monetary assets are included. As aggregations get broader, correlation coefficients with monthly GDP increase, and Divisia aggregates show more obvious advantages over simple sum. Moreover, with smaller standard deviations, Divisia aggregates show better stability compared to simple sum aggregates.

Table 3. The data summary for different monetary aggregates (2000–2020).

	Min.	Max.	Range	Mean	Std.Dev	Cor(,GDP)
Simple sum M1	44,679	625,581	580,902	259,632.2	176,712.4	0.9872589
M_1^c	44,848.81	614,508.2	569,659.4	255,626.5	173,407.6	0.9872337
Simple sum M2	116,293.4	1,989,887	1,873,594	780,288.2	562,083.5	0.9881089
M_2^c	116,091	1,839,876	1,723,785	733,839.6	515,714.4	0.9886445
Simple SumM3	121,220	2,234,298	2,113,078	850,844.1	637,900.8	0.9863492
M_3^c	120,593.4	1,945,297	1,825,704	767,073.1	546,655.6	0.9880806

Noted that, not like the United States and some other developed countries with zero demand deposit interest rates (Wu and Xia 2016), China's bank still pays interest for demand deposits (Miranda-Agrippino et al. 2020). As a result, DM1 shows differences from simple sum M1 in our results. In fact, with zero interest rates, Divisia reduces to a simple sum.

Trend comparisons between Divisia aggregates and simple sums are shown in Figure 6.

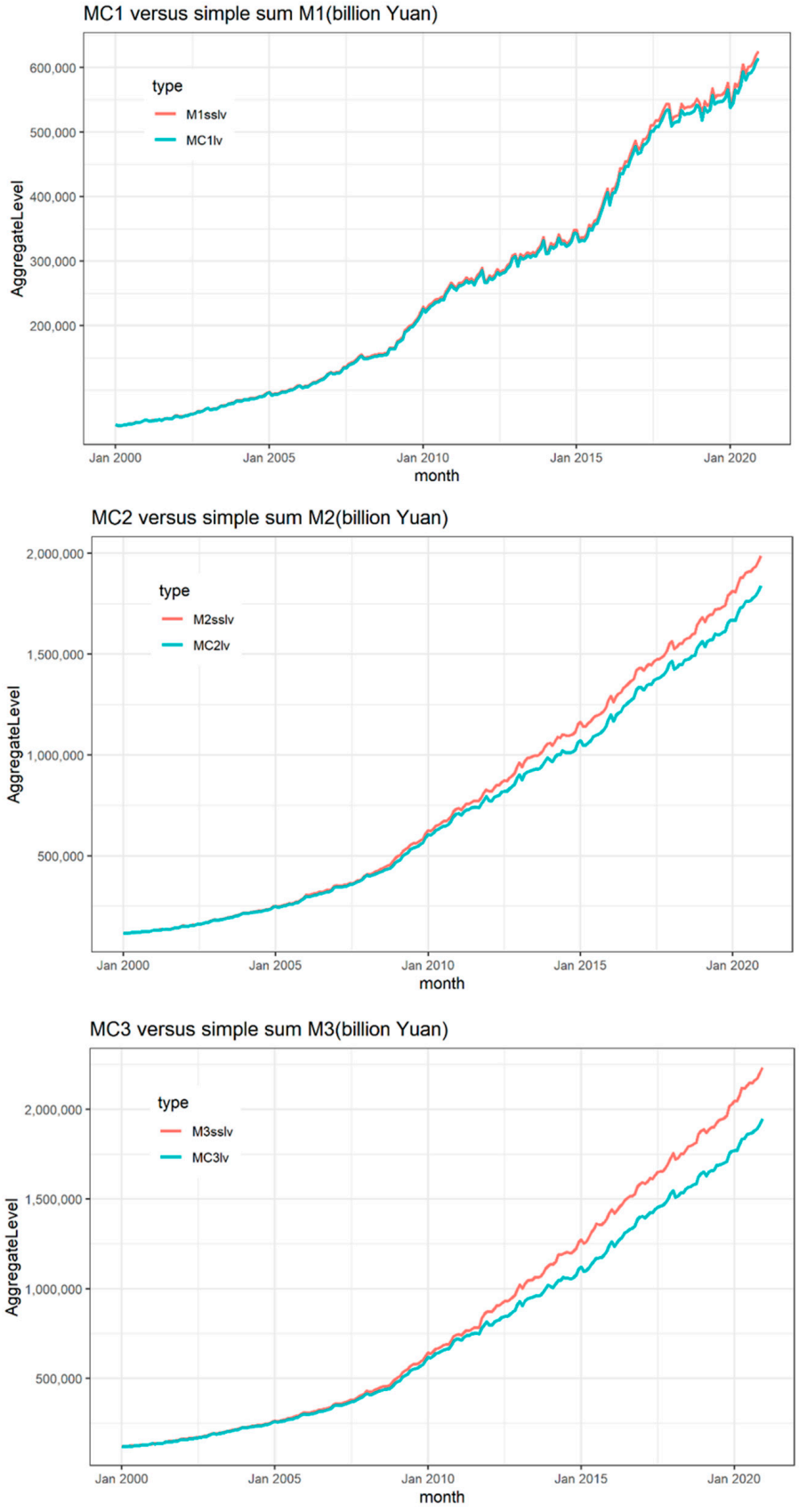

Figure 6. Divisia monetary aggregates and simple sum (billions of Yuan).

3.4. China Monetary Aggregation and Macroeconomic Cycles

To explain the low correlation between Consumption Loan Augmented Divisia Aggregates in the short run, we apply spectral analysis. We adopt the detrended stationary series, while applying spectral estimation by a smoothed periodogram. Dickey–Fuller Test results of all related detrended series are included in the Appendix A. More details and related results can be found in Barnett and He (2020) and Appendix B.

Figures 7 and 8 depict the coherencies between different monetary aggregates and nominal GDP. By focusing on the coherencies with short periods, Figure 8 provides more accurate numerical results for short-term coherencies.

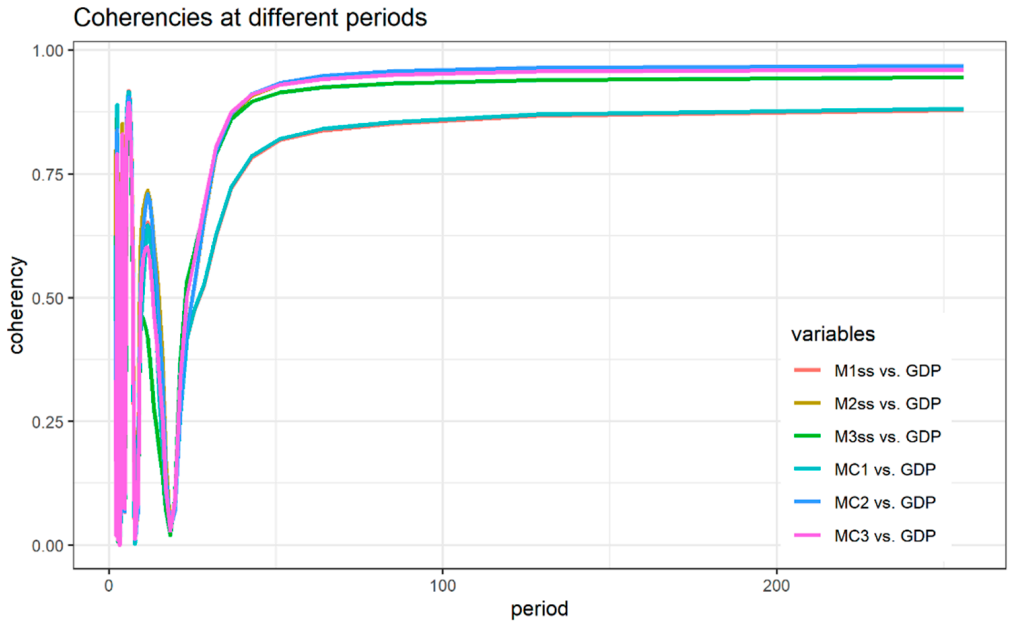

Figure 7. Coherencies with all periods.

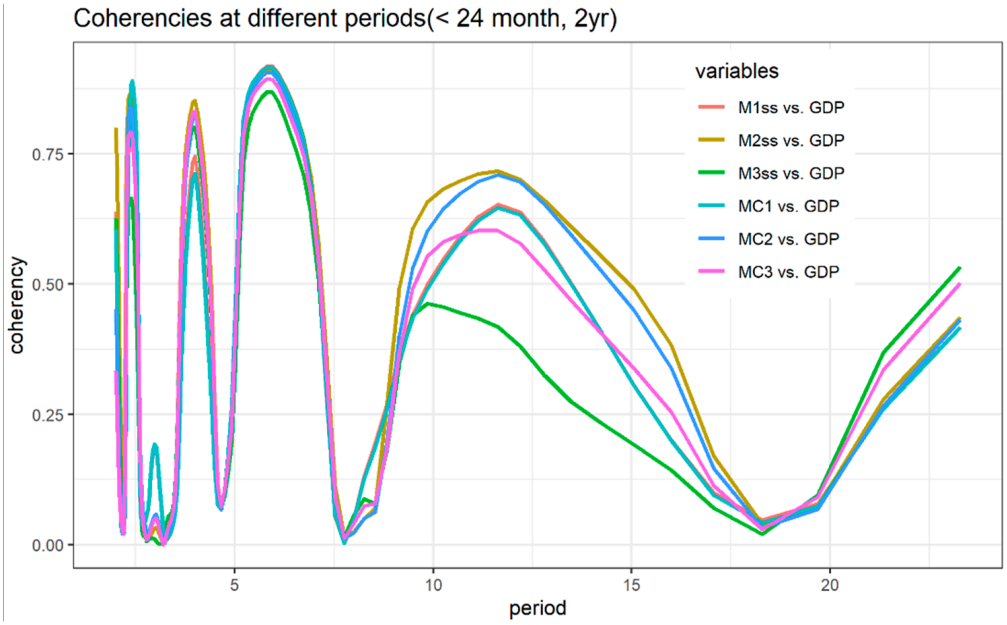

Figure 8. Coherencies with short periods.

Figure 7 shows the coherencies between monetary aggregates and nominal GDP during all periods. In the long run (period > 5 years), all coherencies tend to converge to

a certain level: Coherencies between DM2 and nominal GDP and coherencies between DM3 and nominal GDP converge towards 0.95, while coherencies between simple sum M3 and nominal GDP converge to around 0.92. Coherencies between simple sum M2 and nominal GDP, between simple sum M1 and nominal GDP, and between DM1 and nominal GDP all converge towards 0.875. We can conclude that all monetary aggregates maintain a high correlation with nominal GDP in the long run, especially for broad Divisia monetary aggregates.

Figure 8 shows the coherencies between monetary aggregates and nominal GDP during short periods. In the short run (period < 2 years), all coherencies tend dramatically to oscillate around 0.5, which is almost half of the coherencies in the long run. This result shows the limit and unstable correlation between all monetary aggregates and nominal GDP in the short run. That fact also explains the statistical results for consumption loan augmented Divisia Monetary Aggregates in Section 3.2.

Figures 9 and 10 depict the phase differences between different monetary aggregates and nominal GDP. By focusing on the phase differences during short periods, Figure 10 provides more accurate numerical results for short-term phase differences.

Comparing the phase differences in the short run and long run, we conclude that in the long run, there is no lag between monetary aggregates and nominal GDP, while in the short run (period < 2 years), phase differences are negative for most times, displaying an obvious lag between all monetary aggregates and nominal GDP. This result provides evidence of Milton Friedman's conclusion that targeting the quantity of money in the short run is questionable.

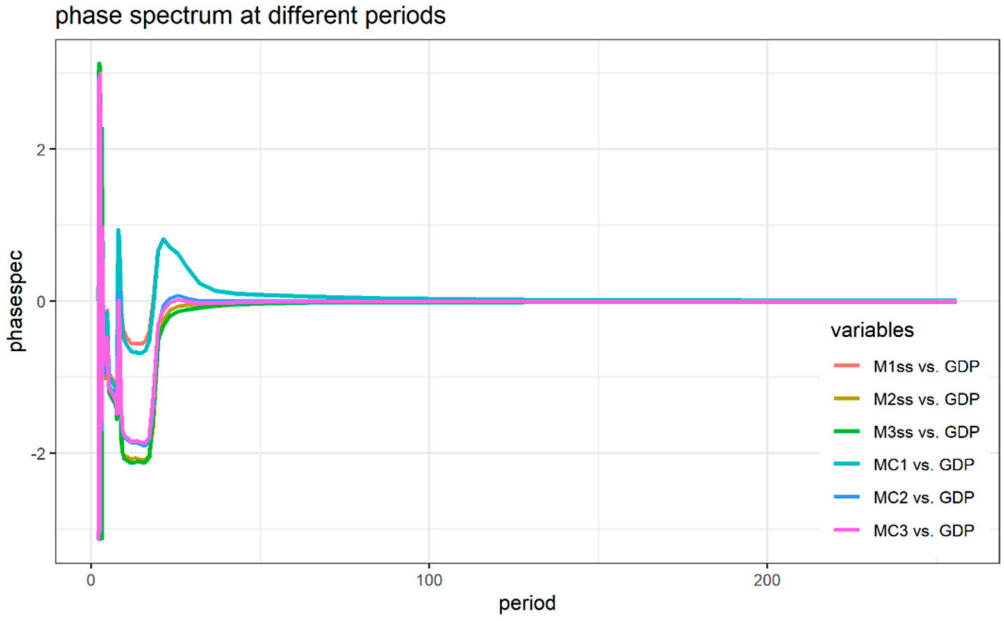

Figure 9. Phase differences with all periods.

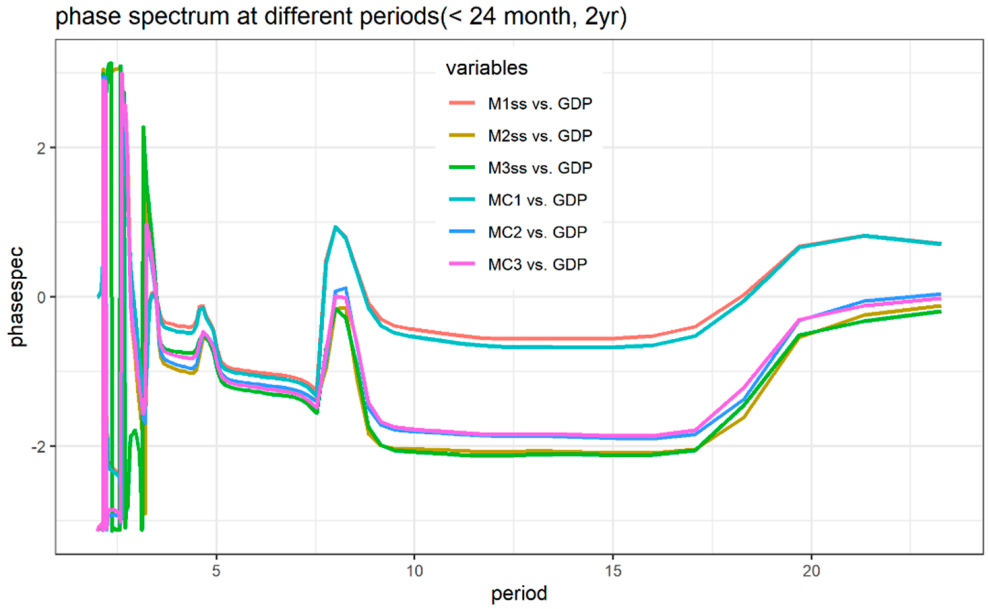

Figure 10. Phase differences with short periods.

4. Augmented Divisia Monetary Aggregation and New Monetary Assets

The latest extension of Divisia Monetary Aggregation was developed in 2020 by Barnett and Su (2020), who derive the credit card services augmented Divisia Monetary Aggregates from the supply side. In Section 2, we developed the consumption loan augmented Divisia Monetary Aggregates and displayed their relevancy and advantages with China's data.

Furthermore, by including debt basis consumption loans in the framework of Divisia Monetary Aggregation, we could generalize the Divisia Monetary Aggregates further to include broader sources of transaction services.

Central Bank Digital Money has been adopted and developed by central bank in many countries. Related programs include Jasper Canada, Ubin Singapore, Stella Japan, Inthanon Thailand, LionRock Hongkong China, and PBC Digital China. These paperless currencies issued by central banks could serve as cash in Divisia monetary aggregates once available and published.

Virtual Currency is currency held within the blockchain network that is not controlled by a centralized banking authority. Virtual currency is different from digital currency, since digital currency is currency issued by a bank in digital form. The most well-known virtual currency is Bitcoin Cash, which is available on Paypal and other online payment systems. If it were to become acceptable for purchase of all goods, it could be included in Divisia monetary aggregates as enjoying similar liquidity with demand deposit balances.

In the future, we could incorporate various types of new currencies into monetary aggregates based on Divisia Monetary Aggregation Theory. Current components for potential augmented Divisia Monetary Aggregates are summarized in Table 4.

Table 4. Components for New Currency Augmented Divisia Monetary Aggregation.

Divisia Monetary Aggregates					Type
M_4^c	M_3^c	M_2^c	M_1^c	M_0^c	Cash
					Central Bank Digital money
					Credit Card Services
					(E-commerce) Consumption Loans
					Virtual currency
					Demand Deposits
					Fixed Deposits in Commercial Banks
					Negotiable Certificate of Deposit
					Saving Deposits in Commercial Banks
					Fixed Deposits in Finance Companies
					Saving Deposits in Finance Companies
					Overnight and Term Repurchases
					Business Paper and Bills
					Treasury Bills

5. Conclusions

Unlike the simple summed monetary aggregates, Divisia Monetary Aggregation has a solid theoretical basis from economic aggregation and index theory. Our empirical results with buy-now-pay-later services and China's data in the long horizon once again demonstrate its superiority as an indicator or as a possible economic intermediate target of policy.

By expanding the Divisia Monetary Aggregates to include buy-now-pay-later services and cryptocurrencies, a more thorough and more precise framework of money aggregation has become relevant to the ever-changing market. As the development of digital money and online payment services continues to expand in China and elsewhere, the Divisia Aggregates could be further augmented by more types of emerging monetary assets once their properties and market acceptability satisfy the weak separability existence condition needed for inclusion in the monetary aggregator function.

Divisia Aggregates are the most advanced measure of liquid asset services. E-commerce Consumption Loan Divisia Aggregates display relevant correlation with the macroeconomic environment. With a longer time horizon, Divisia Monetary Aggregates show higher coherency with nominal GDP compared with simple sum aggregates. Combining their strong theoretical foundations with our empirical results, the Divisia Monetary Aggregates, including consumption loan services, merit serious consideration as an economic indicator of policy and as a possible intermediate target for Central Bank policy in China.

More generally, we recommend that all central banks replace the defective simple sum aggregates with Divisia Monetary Aggregates as superior measures of monetary service flows in the economy. This study is only one of the hundreds throughout the world reaching that conclusion, as displayed in the online library at the Center for Financial Stability in New York City. This paper emphasizes that the relevancy of Divisia monetary aggregation will continue to grow as innovations in money markets continue to expand.

Furthermore, we expand upon Divisia monetary aggregation to include buy-now-pay-later services for the first time for the one country that is already providing those services in a manner satisfying the relevant weak-separability existence condition for inclusion in Divisia monetary aggregates.

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Data Availability Statement:

- Publicly available datasets of China's simple summed monetary aggregates were analyzed in this study. This data can be found here: http://www.pbc.gov.cn.
- China's Divisia monetary aggregates data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

1. Dickey–Fuller Test of detrended simple sum M1 series (taking first order difference)

> adf.test(m1ss_df1)
Augmented Dickey-Fuller Test
data: m1ss_df1
Dickey–Fuller = −4.0332, Lag order = 6, *p*-value = 0.01
alternative hypothesis: stationary

2. Dickey–Fuller Test of detrended simple sum M2 series (taking first order difference)

> adf.test(m2ss_df1)
Augmented Dickey–Fuller Test
data: m2ss_df1
Dickey–Fuller = −6.0718, Lag order = 6, *p*-value = 0.01
alternative hypothesis: stationary

3. Dickey–Fuller Test of detrended simple sum M3 series (taking first order difference)

> adf.test(m3ss_df1)
Augmented Dickey–Fuller Test
data: m3ss_df1
Dickey–Fuller = −6.4781, Lag order = 6, *p*-value = 0.01
alternative hypothesis: stationary

4. Dickey–Fuller Test of detrended DM1 series (taking first order difference)

> adf.test(mc1_df1)
Augmented Dickey–Fuller Test
data: mc1_df1
Dickey–Fuller = −3.9313, Lag order = 6, *p*-value = 0.01293
alternative hypothesis: stationary

5. Dickey–Fuller Test of detrended DM2 series (taking first order difference)

> adf.test(mc2_df1)
Augmented Dickey–Fuller Test
data: mc2_df1
Dickey–Fuller = −5.3884, Lag order = 6, *p*-value = 0.01
alternative hypothesis: stationary

6. Dickey–Fuller Test of detrended DM3 series (taking first order difference)

> adf.test(mc3_df1)
Augmented Dickey–Fuller Test
data: mc3_df1
Dickey–Fuller = −5.6016, Lag order = 6, *p*-value = 0.01
alternative hypothesis: stationary

7. Dickey–Fuller Test of detrended monthly GDP series (taking first order difference)

> adf.test(gdp_df1)
Augmented Dickey–Fuller Test
data: gdp_df1
Dickey–Fuller = −8.8287, Lag order = 6, *p*-value = 0.01
alternative hypothesis: stationary

Appendix B

R code example for Spectrum Analysis of detrended time series

```
#m1 simple sum and gdp
m1ss_gdp_df1 <- cbind(m1ss_df1, gdp_df1)
m1ss_gdp_df1_spec <- spec.pgram(m1ss_gdp_df1, spans = c(8,8),detrend=TRUE)
legend("topright",legend=c("M1 ss","GDP"),col = c(1,2),lwd=1)
plot(m1ss_gdp_df1_spec, plot.type = "coherency")
plot(m1ss_gdp_df1_spec, plot.type = "phase")
```

1. spec.pgram calculates the periodogram using a fast Fourier transform and optionally smooths the result with a series of modified Daniell smoothers (moving averages giving half weight to the end values). The raw periodogram is not a consistent estimator of the spectral density, but adjacent values are asymptotically independent. Hence, a consistent estimator can be derived by smoothing the raw periodogram, assuming that the spectral density is smooth.

Notes

[1] Huabei has also been called Ant Check Later services. See Xie et al. (2020). However, to avoid confusion from translating issues, we adopt its original product name in this paper.

[2] Treasury Bills, negotiable certificate of deposit, and commercial paper have not been regularly published by PBC, so are not included in this paper. Accessed on 13 Feburay 2021.

[3] Original prospectus can be found at https://www.niutoushe.com/wpcontent/uploads/file/20201105/1604567173445605.pdf. Accessed on 13 Feburay 2021.

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