

14.462
Spring, 2020

**e-Money, Infrastructure and Liquidity
Shortages, Financial and Trader
Centrality, and Optimized Liquidity
Injections as Monetary Policy**

(Lecture 3)

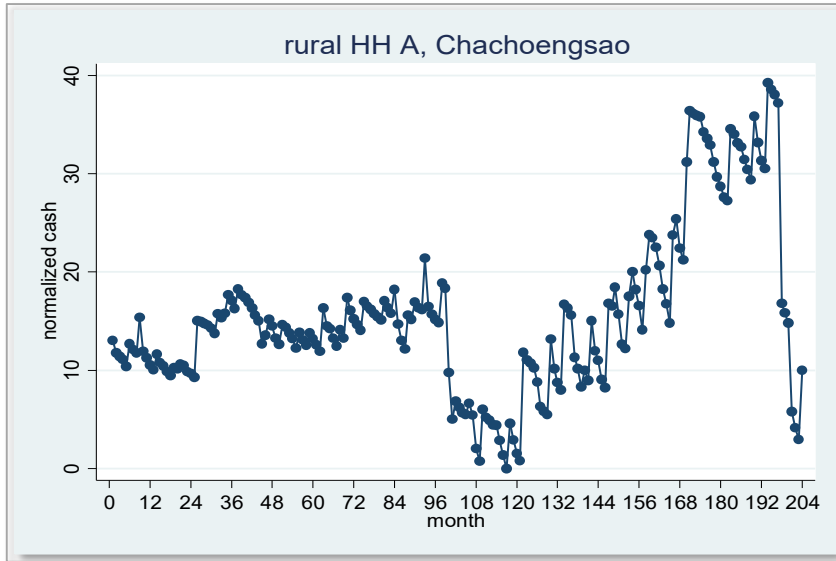
Robert M. Townsend

Elizabeth & James Killian Professor of Economics, MIT

e-Messages and e-Value Transfer

Second component of distributed ledgers

Outline: From Cash Flow Accounts in Thailand



Money in Terms of Monthly Consumption						
	mean	sd	p25	p50	p75	N
Total	45	37	21	32	57	531

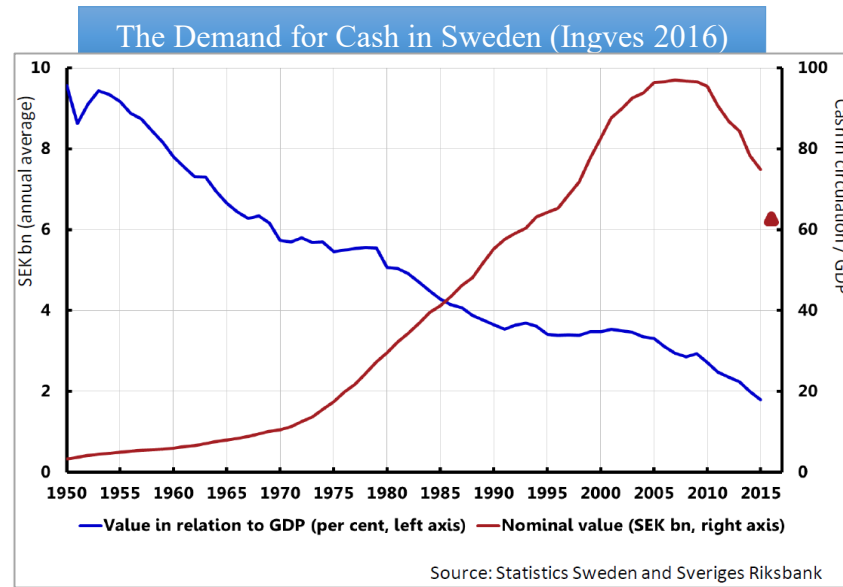
Table 3: Empirical Frequency and Size of Adjustments

Occupation	Statistics	Frequency of Adjustments		Avg. Size of Adjustment	
		Deposits	Withdrawals	Deposits	Withdrawals
All	mean	15.6	10.3	0.267	0.869
	median	16.2	8.7	0.172	0.569

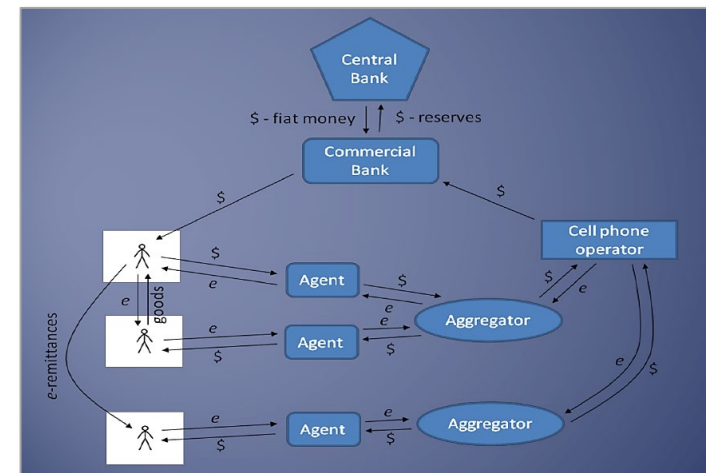
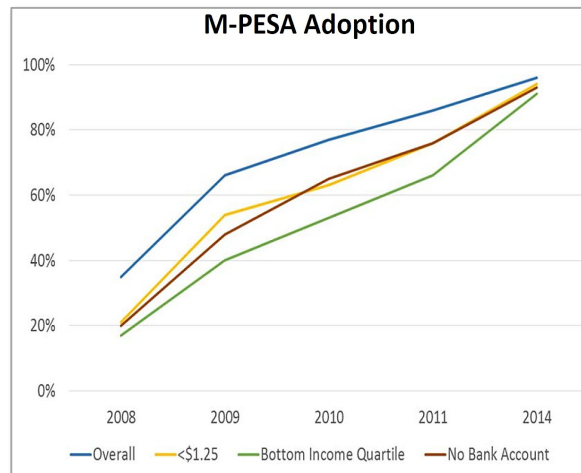
Frequency of Adjustment is number per year. Size of Adjustments is in terms of average household monthly consumption. Adjustment is the sum of formal (i.e. at financial intermediaries) and informal adjustments (to other households). Adjustments on different accounts are regarded as different adjustment.

To Sweden as virtual e-world, with e-money to Kenya In between, with welfare gains

- ❖ Sweden, almost no currency left



- ❖ Kenya: Phone credits and e-transfers
- ❖ cash in and out through agents
- ❖ Coexistence of payments devices: e-money and shillings as token
- ❖ Remittances, e-transfers from migrants, lead to better insurance, welfare gains



Limitations: The Issue of Trust

❖ Safaricom as trusted third party

- Token transfer systems rely on distributed ledgers, with immutable records and some kind of consensus validation

❖ Taking into account the larger financial system, banks hold Safaricom accounts, and hence customer shilling accounts, and are subject to runs. Again, the issue of trust

Missing Infrastructure and Liquidity Policy

- ❖ Liquidity issues in practice: common problems span a range of economies
 - Kenya
 - Shortages among the agents: running out of e-money and/or fiat
 - Indonesia, agents acting on behalf of banks- complain about liquidity
 - US financial markets, broker shortages, liquidity as insurance
- ❖ Infrastructure currently in pieces: Cryptocurrency exchanges are largely built as traditional systems with (trusted) brokers or centralized exchanges, in contrast to the tokens themselves
 - Begs consideration of overall market design
 - Begs issue of crypto and monetary policy

Cash Management in Village Thailand: Positive and Normative Implications

Fernando Alvarez

University of Chicago

Anan Pawasutipaisit

Thammasat University

Robert M. Townsend

Elizabeth & James Killian Professor of Economics, MIT

2015 Bank of Canada Annual Conference

“Electronic Money and Payments”

Ottawa, Ontario

November 20, 2015

Existing Models of Cash Management: Baumol-Tobin and Miller-Orr

- ❖ Let c be a given level of expenditure that agent has to spend within a year
- ❖ Let n be total number of trips to withdraw cash at bank within a year
- ❖ Let M be average cash holding
- ❖ Let W be amount of withdrawal
- ❖ Let R be interest
- ❖ Let b be transaction cost per trip
- ❖ Given this setup, if cash holding is for transaction purpose, then its pattern would be sawtooth where each withdraw,

$$W = \frac{c}{n}$$

- ❖ and the average cash holding will be

$$M = \frac{W}{2} = \frac{c}{2n}$$

- ❖ To determine optimal cash holding: We compute the forgone interest and the transaction cost. The forgone interest would be $RM = R \frac{c}{2n}$ while the transaction cost for all trips is bn . The total cost of cash management is thus $R \frac{c}{2n} + bn$.

- ❖ So $n = \left(\frac{Rc}{2b}\right)^{1/2}$ $M = \left(\frac{cb}{2R}\right)^{1/2}$

Miller-Orr

- ❖ Baumol-Tobin model should apply reasonably well to the household sector, particularly to salary-earning households.
- ❖ Miller and Orr (1966) proposed a model of the demand for cash for firms.
- ❖ For many business firms, the typical pattern of cash management is not simple, regular and predictable.
- ❖ The cash balance fluctuates irregularly (and to some extent unpredictably) over time in both directions (up and down), building up when operating receipts exceed expenditures and falling off when the reverse is true.
- ❖ If the build-up is at all prolonged, a point is eventually reached at which the owner/manager/financial officer decides that cash holdings are excessive, and transfers a sizable quantity of funds to some other source.
- ❖ In the other direction, in the face of a prolonged net drain, a level will be reached at which the owner/manager/financial officer will do something to restore the cash balance to an “adequate working level”.

Model

❖ The basic ingredients of the model are as follows:

- Let $e = c - y$ be net expenditures. So $e(t) > 0$ means an expenditure paid in cash at time t and $e(t) < 0$ means an income received in cash.
- We assume that the net expenditures in cash are iid through time and that during a period of length Δ they are distributed as follows:

$$e(t) = \begin{cases} z_p & \text{with probability } \kappa_p \Delta \\ \Delta c + \sigma \Delta^{1/2} & \text{with probability } \frac{1 - (\kappa_p + \kappa_n) \Delta}{2} \\ \Delta c - \sigma \Delta^{1/2} & \text{with probability } \frac{1 - (\kappa_p + \kappa_n) \Delta}{2} \\ -z_n & \text{with probability } \kappa_n \Delta \end{cases}$$

Model (cont.)

- ❖ That is, net expenditures are the sum of two components, one is small recurrent net expenditures and one is infrequent lumpy ones. The small recurrent expenditures have mean c and variance σ^2 per unit of time. We will take κ_i to be a small number, so most of the time or with probability $1 - (\kappa_p + \kappa_n)\Delta$, there are only small recurrent expenditures. But when a large net expenditure occurs, which happens with small probability κ_i per unit of time, half of the time are purchases (or outflows of cash) and half of the time incomes (inflows of cash).
- ❖ As $\Delta \rightarrow 0$, the cumulative value of net expenditures is the sum of Brownian motion with drift c and volatility σ , and two independent Jump process, with Poisson arrival rates κ_p κ_n and jump size z_p and $-z_n$.
- ❖ The evolution of cash will be as follows:

$$m(t + \Delta) = m(t) - e(t + \Delta) + w(t + \Delta) - d(t + \Delta)$$

where w is withdrawal and d is deposit which is action that households can take. In case of inaction, $w = d = 0$ and thus cash will either go up or go down, depending on whether net expenditure is negative or positive.

Model (cont.)

- ❖ Household wants to minimize the expected discounted value of the sum of two costs
 - Flow opportunity cost
 - Adjustment cost
- ❖ We assume that costs are discounted at a real rate r per unit of time, and cash holdings have opportunity cost R per period. Given iid assumption, the state of the problem is given by cash holdings m . Let $V(m)$ be the value function right before the agent makes the decision of whether or not to take action, i.e., withdraw or deposit. And assume that cash cannot be negative, or non-negativity constraint, household will thus be forced to take action when $m \leq 0$.

Value Function

❖ The value function will satisfy the following Bellman equation:

$$V(m) = \begin{cases} b + \min_{m'} V(m') & \text{if } m \leq 0 \\ \min \left\{ \begin{array}{l} b + \min_{m'} V(m'), \\ \Delta Rm + \frac{1}{1+\Delta r} E[V(m-e)] \end{array} \right\} & \text{if } m > 0 \end{cases}$$

where

$$\begin{aligned} E[V(m-e)] = & V(m+z_n) \kappa_n \Delta \\ & + V\left(m - \Delta c + \sigma \Delta^{1/2}\right) \frac{1 - (\kappa_p + \kappa_n) \Delta}{2} \\ & + V(m-z_p) \kappa_p \Delta \\ & + V\left(m - \Delta c - \sigma \Delta^{1/2}\right) \frac{1 - (\kappa_p + \kappa_n) \Delta}{2} \end{aligned}$$

i.e., if cash right before the agent makes the decision is negative, households must take an action, and when they do, that will incur transaction cost b and households will choose to have cash such that the value function is minimized; there is no discounting because it happens right away. But if cash right before the agent makes the decision is positive, household will choose to either take action or take no action, by comparing the value of adjusting with the value of inaction, and choose the one that gives lower cost.

Data

Net Cash Variables

- ❖ Net cash outflow is defined as exogenous cash outflow minus exogenous cash inflow.
- ❖ Net cash outflow can be defined two ways, depending on whether we consider only formal endogenous variables or both formal and informal ones
- ❖ With only formal endogenous variables, net cash contains the following variables that we treat as exogenous

Exogenous cash outflow	Exogenous cash inflow
c	y
assets purchase	assets sold new
repayment in borrowing new	borrowing
lending	repayment in lending
gift outflow	gift inflow
ROSCA outflow	ROSCA inflow

- ❖ The actions that households choose are

Exogenous cash outflow	Exogenous cash inflow
$n_d D$	$n_w W$

Including Informal

- ❖ With both formal and informal endogenous variables, net cash contains the following variables that we treat as exogenous

Exogenous cash outflow	Exogenous cash inflow
c	y
assets purchase	assets sold ROSCA
ROSCA outflow	inflow

- ❖ The actions that households choose are

Exogenous cash outflow	Exogenous cash inflow
$n_d D$	$n_w W$
repayment in borrowing	new borrowing
new lending	repayment in lending
gift outflow	gift inflow

Treatment of the Data

- ❖ Basically, the idea is making sure that data is in cash. The following variables contain some data issue

Cash inflow	Cash outflow
y	$n_d D$
new borrowing	

- ❖ Other variables such as consumption expenditure, gift, and lending are relatively easy to make sure that they are in cash.

$n_d D$ or Actual Deposit

- ❖ The monthly survey does not have withdrawal and deposit per transaction. It does not have frequency of withdrawal and deposit and its average size per month. It has total amount of deposit, and withdrawal since the past interview (approximately 1 month).
- ❖ But there is some confusion in recording the values. From the survey data, we often see that households make deposits and withdrawals at the same month, an observation which is not consistent with the idea that it is costly for households to adjust cash holding by going to the bank.
- ❖ This is because the survey team will record when money goes into savings accounts as a deposit, regardless of whether households made deposits by themselves. For instance, if households receive direct deposit, or money transfer from some organization, they will be treated as deposits in the survey.
- ❖ But for our purpose, this distinction is crucial. So we have to fix this and make sure that deposit is in cash and it is done by household itself.

y or Income in Cash

- ❖ There are two types of income that households may receive as direct deposit but somehow they are recorded as cash in the survey
 - Salary from employer
 - Revenue from selling milk to milk cooperatives for dairy farmers in Lopburi
- ❖ For salary from employer, we isolate wages received as direct deposit using variables in job form (to get information about type of worker and type of payment) and job module (to get payment each month)
- ❖ We focus on employees with monthly wages, or government workers with monthly wage/salary, then using this condition from the job form and match it at individual-job level to get monthly wage.
- ❖ Then we check it with deposit from savings module when source of deposit is "from salary or wages", and use the code from the Thai survey team that indicates whether household made deposit by itself or else.

y or Income in Cash (cont.)

- ❖ We merge this file with the one that contains livestock revenue, but livestock revenue might be something else (besides dairy cow)
- ❖ Then we merge it with the file from the Thai survey team which indicates whether household made deposit by itself or else.
- ❖ So the condition used finally are
 - Source of deposit is from selling agricultural product
 - Household did not make deposit by itself (because in this case, milk cooperative made it)
 - Having revenue from livestock from Lopburi (province that has milk cooperative)
- ❖ We checked the difference between revenue livestock and deposit for these households, about 85% match perfectly

Table 1: Net Cash Consumption for Rural Thai Households

	Median ^a	Mean ^a	Std Dev ^a
$\mathbb{E}[e]$	-.0149	-0.131	0.938
$\text{Var}[e]$	4.00 ²	5.08 ²	6.41 ²
kurtosis[e]	20.54	30.74	25.87
skewness[e]	1.208	0.694	4.111
$\text{Corr}[e, e']$	0.012	0.032	0.134
$\kappa_p \Delta$	0.025	0.028	0.022
z_p	14.32	22.62	28.14
$\kappa_n \Delta$	0.016	0.018	0.016
z_n	13.37	23.17	66.88

289 households with active savings account. e : monthly net cash consumption, normalized by average monthly household consumption. ^a: Mean, Median and Std Dev across households of corresponding statistic. z_p : average value of e if $e > 2\text{Std}[e]$. $\Delta \kappa_p$: fraction of months for which $e > 2 \text{Std}[e]$. z_n : average value of $|e|$ if $e < 2\text{Std}[e]$. $\Delta \kappa_n$: fraction of months for which $e < 2 \text{Std}[e]$.

$$\mathbb{E}[e] = \Delta [c + \kappa_p z_p - \kappa_n z_n] \quad (36)$$

$$\mathbb{E}[e^2] = (1 - \Delta(\kappa_n + \kappa_p)) (\Delta^2 c^2 + \Delta \sigma^2) + \kappa_p \Delta (z_p)^2 + \kappa_n \Delta (z_n)^2 \quad (37)$$

❖ We use this simple statistical model to back up c and σ from equations (36) and (37) given $\mathbb{E}[e]$, $\mathbb{E}[e^2]$, κ_p , z_p , κ_n , and z_n .

Cash Holding

Table 2: Net Cash Consumption for Rural Thai Households by Occupation

Occupation		Statistics						Implied Values	
		$\mathbb{E}[e]$	$Std[e]$	$\kappa_p \Delta$	z_p	$\kappa_n \Delta$	z_n	$\frac{\Delta c}{N_a}$	$\frac{\sqrt{\Delta} \sigma}{M}$
All	mean	-0.13	5.08	0.028	22.62	0.018	23.16	-0.36	1.20
	median	-0.015	3.99	0.025	14.32	0.017	13.37	16.2	2.12

See Table 1 for definition of variables. The mean and median of the statistics across households in the occupation. The implied values of Δc and $\sqrt{\Delta} \sigma$ are the solutions to equation (??) taking as given the mean values for $\mathbb{E}[e], Std[e], \Delta \kappa_p, \Delta \kappa_n, z_p$ and z_n . Given these values N_a is the expected number of adjustment per year, and M the average money holdings, the solution to the optimal policy using $R = 0.05, r = 0.03$ per year and $b = 0.05/30$, where 1 is the monthly average consumption. * indicates a case where the implied solution for σ was negative, so it was set to $\sigma = |c|$.

From the model

Measuring Cash

- ❖ All transactions in the monthly data are recorded as in cash or in kind.
- ❖ We do not know initial cash balance (decided not to ask). But we do see measured cash transactions, so we guess initial stock is zero (most conservative estimate). And if balance goes negative in some month, we add to initial stock so balance would be positive.
- ❖ We still see trends in the data and it seems cash is a store of value for year to year, even life cycle. This is an even bigger Anomaly!
- ❖ To study transaction demand, we “detrend” as best we can. Cash consumption number is adjusted so that on average, net cash of household inflow of those who have inflow more than outflow now will be zero (or as close as possible).
- ❖ Then, use this adjusted cash consumption to compute new *net_cash*, and the statistics are based on active user only.

Money Holding, Frequency and Size of Adjustments: Data vs. Model at Plausible Values

Money in Terms of Monthly Consumption						
	mean	sd	p25	p50	p75	N
Total	45	37	21	32	57	531

Table 3: Empirical Frequency and Size of Adjustments

Occupation	Statistics	Frequency of Adjustments		Avg. Size of Adjustment	
		Deposits	Withdrawals	Deposits	Withdrawals
All	mean	15.6	10.3	0.267	0.869
	median	16.2	8.7	0.172	0.569

Frequency of Adjustment is number per year. Size of Adjustments is in terms of average household monthly consumption. Adjustment is the sum of formal (i.e. at financial intermediaries) and informal adjustments (to other households). Adjustments on different accounts are regarded as different adjustment.

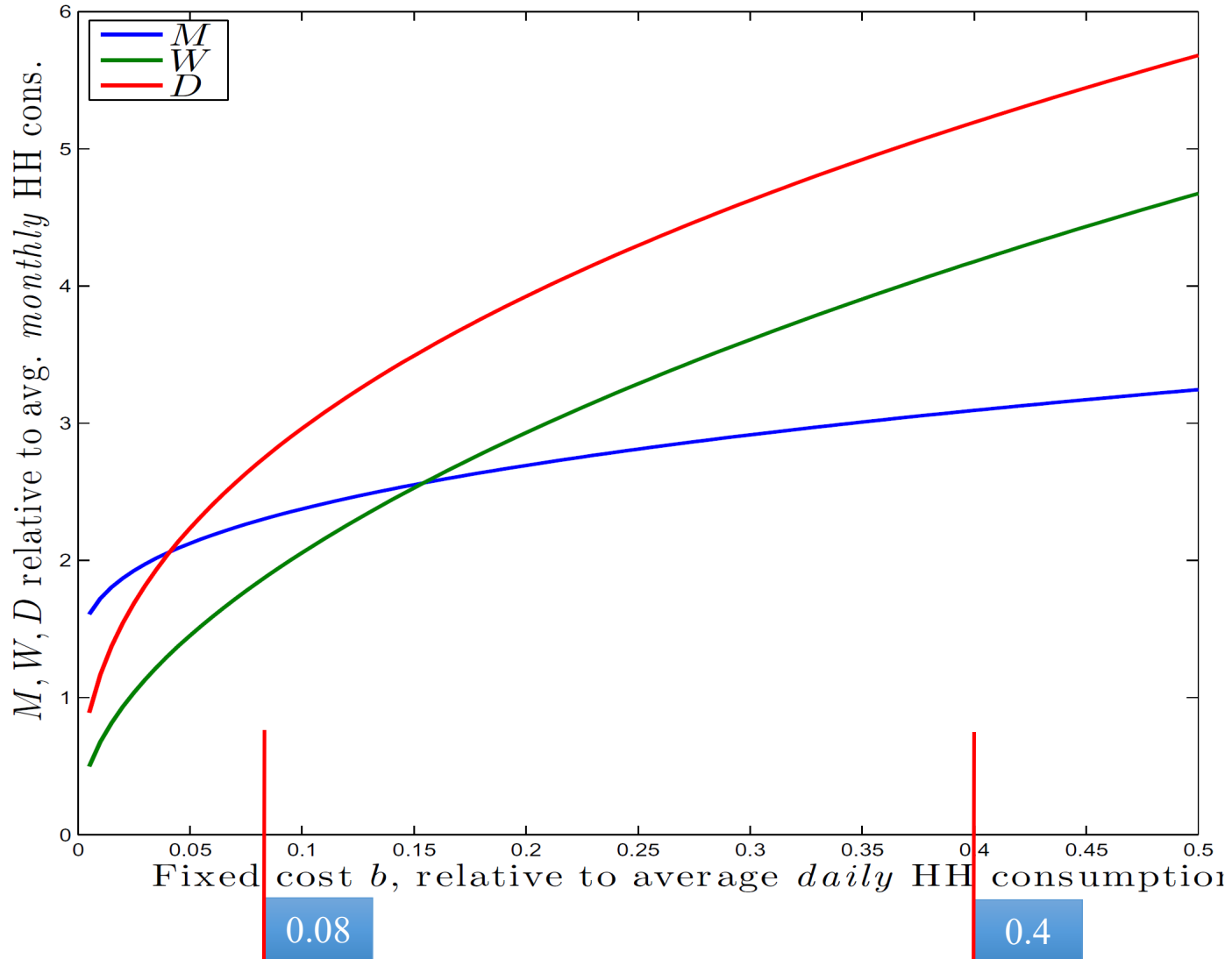
Table 4: Model Frequency and Size of Adjustments

Occupation	b/R	Frequency of Adjustments		Avg. Size of Adjustment	
		Deposits	Withdrawals	Deposits	Withdrawals
All	0.4	6.95	9.21	2.23	1.45
	0.08	17.9	27.7	1.17	0.676

Parameter values $r = 0.02$, $R = 0.05$ per year and $b = 0.05/30$ and $b = 0.01/30$. The remaining parameter values can be found on [Table 2](#).

Cash as a Function of Fixed Cost

Figure 1: Avg. cash balances M and agv. size of withdrawals W and deposits D



A Model That Matches National, Rural or Even Monthly Data (But At Implausible Parameter Values)

- ❖ We set parameters as in Thai data as before in the benchmark
- ❖ Then to match the frequency of transactions we allow free withdrawals (or deposits) at the observed frequency, 16 per year
- ❖ Finally we raise the cost b for all trips, quite high

Modify Benchmark Model

- ❖ The case where discount rates are the same
 - compares cases that have free adjustment opportunities with cases without free adjustment opportunities.
- ❖ Cash balances as well as the frequency of total adjustment are the same, as long as $\kappa_f + \kappa_n + \kappa_p$ stays constants.
- ❖ Only difference is on
 - the average size of deposits and withdrawals
 - and potentially on the ratio of the number of deposits to withdrawals.

❖ The mechanism of free adjustment opportunities and the one of large net cash purchases are substitutes to explain the size of cash balances and frequency of adjustments.

❖ Consider the following two setting of the parameters: θ and θ' with θ_0 and θ'_0 and with:

$$\kappa_f = 0, \quad \kappa_f + \kappa_n + \kappa_p = \kappa'_f + \kappa'_n + \kappa'_p \quad \text{and} \quad r = r'$$

❖ Assume that for θ the optimal policy is such that large net cash expenditure shocks trigger an adjustment, i.e. that

$$\min \{z_n, z_p\} > m^{**}(\theta).$$

❖ Then, the optimal policy thresholds are the same for θ and θ' and the value functions differ from a constant, i.e.:

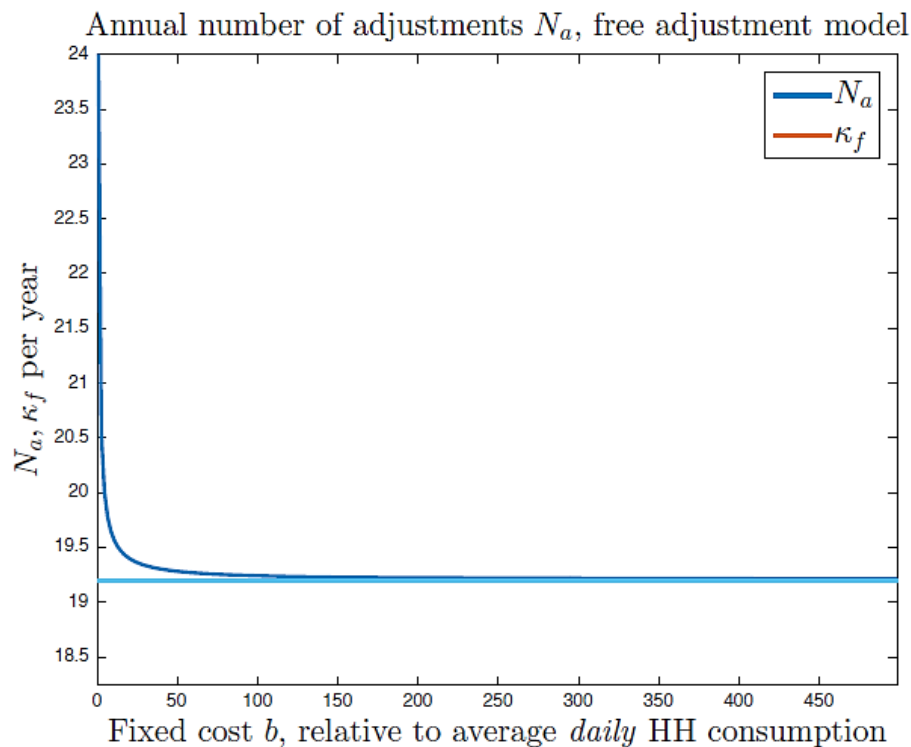
$$m^*(\theta') = m^*(\theta), \quad m^{**}(\theta') = m^{**}(\theta), \quad V(m; \theta') = V(m; \theta) - b \left(\frac{\kappa_f}{r} \right) \quad \text{for all } m$$

❖ Moreover, the distribution of cash holdings, the average cash balances, and the average number of adjustments per unit of time (i.e. sum of deposits and withdrawals) are the same for the two set of parameters, i.e.:

$$f(m; \theta') = f(m; \theta) \quad \text{for all } m, \quad M(\theta') = M(\theta), \quad \text{and} \quad N_a(\theta') = N_a(\theta)$$

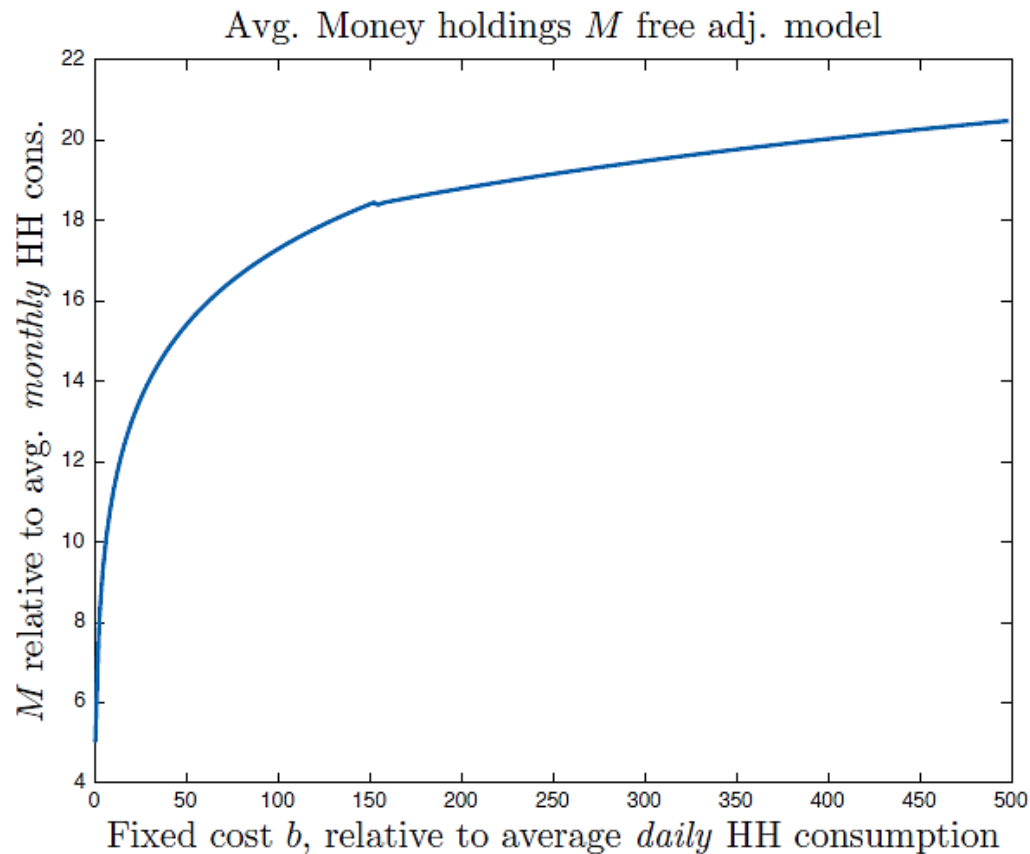
Predicted Model Behavior

- ❖ In the limit households wait for free withdrawals which come at random times.
- ❖ When they do the withdraw the return point m^*
- ❖ If money drifts up and up, there will be an upper bound for deposits
 - this happens rarely,
 - quite expensive when it happens
- ❖ Overall average money balances in steady state will in fact be m^* if all shocks are symmetric
 - as intuition suggests and numerical calculations confirm



Predicted Money

- ❖ To get to $M = 8$, $b > 1$ day
- ❖ To get to $M = 30$, b is ≈ 2 years

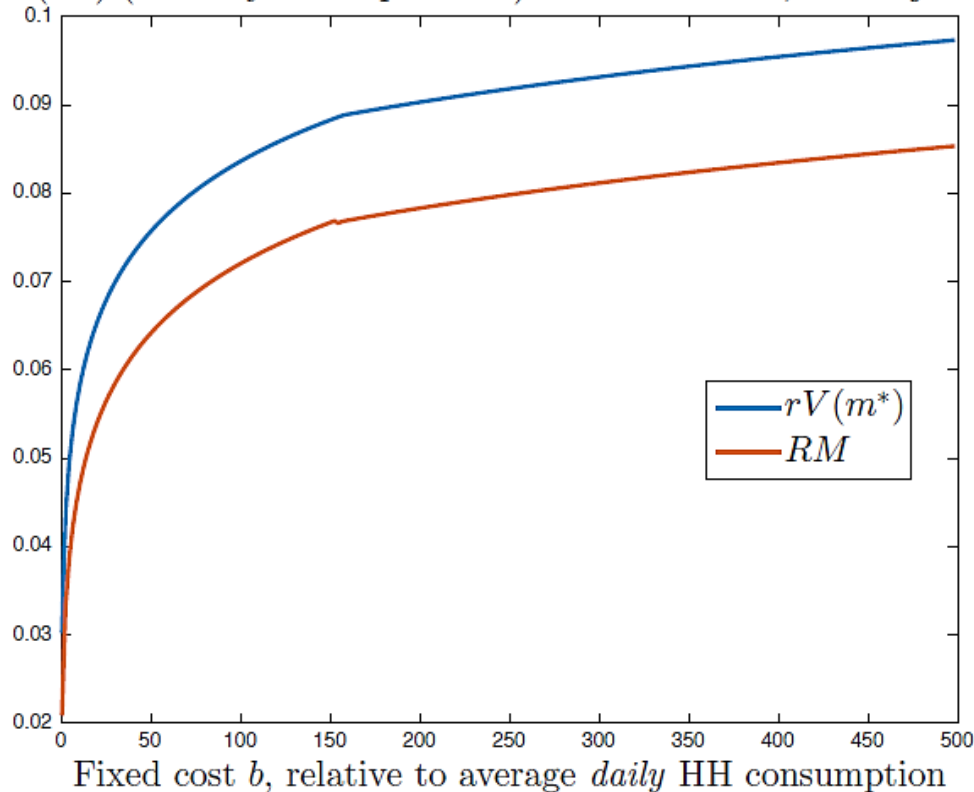


Welfare Costs

❖ The costs, discounted expected present value

- The current value function as a function of current money holdings, in particular m^* , can be calculated
 - Accounting costs at 8%
 - Behavioral model at 9.5% of consumption
- If off by a factor of 4
 - Costs are 2 – 2.5% of monthly consumption

$rV(m^*)$ (monthly flow equivalent) value fcn at m^* , free adj model



Statistics of Normalized Cash in Urban Survey

- ❖ Computing mean of normalized cash, we have about 600 numbers, one for each household. Then look at some key statistics of this distribution.
- ❖ From mean, cash is highest at Lopburi (5.53), then Sisaket (4.78), Chachoengsao (2.79) and Buriram (1.92). This is quite lower than when we don't adjust consumption, or using just cash holding in the household financial account.
- ❖ Overall, cash is about 3.80 times of average monthly consumption.
- ❖ This ranking (between these 4 provinces) also holds for other statistics (median, standard deviation, max, p25, p75).

Measurement in the Rural Data of Transactions

- ❖ In the basic monthly data, much work was done with enumerators to try to distinguish own direct deposit vs deposits made for the household by someone else, which they previously reported as own deposit, the language and concepts, not being clear.
- ❖ Since month 174, there is a measure to distinguish between own and direct deposit in the same rural survey. (due to doubts we have been having). If anything, it appears for the data we are using, the fraction of own deposit that we infer is actually greater than might have been the case for two of the four provinces, judging from what happens afterward, when arguably we have better measurement, from month 174. This means cash holding would have been even larger, so measurement of deposits may be accurate or biased in direction of rural household holding even more cash than we are estimating.
- ❖ In particular, comparing the retrospective measure (month 1-160) with the actual measure (month 174-208), they are quite different for Chachoengsao and Buriram where a fraction of own deposit during month 1-160 is greater than a fraction of own deposit during month 174-208.
- ❖ The post month 174 also appears reasonable and accurate by another standard. If we distinguish down deposit at large institutions (such as BAAC and commercial bank) vs own deposit at small institutions (within village fund), the former are larger and less frequent, consistent with it being more costly to deal with the larger ones. (however overall rural household behavior begs for an explanation as in the next slide)

Household Transactions and Behavior, Rural vs. Urban

- ❖ Basic questions, hypotheses: As cash holding is lower in the urban survey than the rural survey, is it because households in the urban survey deposit more often, and/or larger amounts. And is it because they withdraw less, and/or smaller amounts than households in the rural survey? The answers are mixed but the picture of behavior is becoming clear.
- ❖ Deposits:
 - Households in the rural survey make (own) deposit, more frequently than households in the urban survey.
 - In terms of size of deposit (relative to average monthly household consumption), own deposit in the rural survey is bigger than own deposit in the urban survey except at Sisaket.
 - Thus the evidence goes against the hypothesis for deposits.
- ❖ Withdrawals:
 - Households in the rural survey withdraw more often than households in the urban survey.
 - In terms of size of withdrawal (relative to average monthly household consumption), withdrawal in the rural survey are at a larger size than withdrawal in the urban survey.
 - Thus the evidence is consistent with the initial hypothesis.
- ❖ Behavior:
 - In the urban survey, the ratio of the direct deposit to withdrawal is about 1 on average. Thus it is possible that in the urban survey, withdrawal is mainly from direct deposit, and households use that to finance monthly consumption. They seem to behave as Baumol Tobin type households with respect to direct deposits, put into the financial institution on their behalf.
 - there is in addition for urban some own deposits. so it seems they leave an equivalent amount in the bank, hence not used for consumption, consistent with this, total deposit from any source is greater in urban than in rural.
 - In this sense urban households seem to be managing their money well. In contrast, for rural households, withdrawal is greater than consumption, so this is in part where the cash is coming from. Its hard to reconcile deposit behavior in the rural sample, with their withdrawal behavior, or in short, why put it in a financial institution only to take too much out.
- ❖ Pending: fraction of extreme events in urban and relatedly, what is the source of direct deposit for urban households, relative to their occupation.

Remedies

- ❖ Pro-active training and apps for better currency management
- ❖ Conversion to M-Pesa type with means of payment in the 'bank'
 - Earning interest
 - Virtually costless transfers

Swish and a Virtual e-World

The service works through a smartphone application, through which the user's phone number is connected to their bank account, and which makes it possible to transfer money in real time, a few seconds until confirmation is received by both parties.^[2] The user must have a second mobile application called *Mobilt BankID Säkerhetsapp*, which is an [electronic identification](#) issued by several banks in Sweden. This requires that the user has a bank account in a Swedish bank participating in the system, and also a [national ID number](#). Users who have a Swedish bank account but no suitable phone can register for reception of payments. The phone number can be of another country. The actual transfer is done by the Bankgirot clearing system, which developed instant payments for the Swish system.

Swish was originally intended for transactions between individuals, but soon it started to be used for flea markets and collections at church services,^[5] and by sports clubs and other organisations as payment at small events where a credit card reader would be too expensive or otherwise impractical. Small companies who wished to avoid credit card charges and simplify online payments soon followed suit. In 2014 organisations could register for receiving payments, although some organisations used a private bank account of someone in the organisation before that. In January 2017 Swish was launched for web based sales which quickly became popular, for example used by the train operator [SJ](#).^[6] It is possible to pay by scanning a [QR code](#).

Swish is used for transactions that used to be mostly cash-based.¹

In some cases of media attention towards such cases banks have donated their Swish profit to the organisations.

[https://en.wikipedia.org/wiki/Swish_\(payment\)](https://en.wikipedia.org/wiki/Swish_(payment))

Ingves (2017) “Do we need an e-krona?”

Do we need digital cash – an e-krona as the Riksbank calls it? This is a question currently being analysed and subjected to lively debate in the central bank world. It is scarcely surprising that there is so much interest in this question, given that it covers all of a central bank’s areas of activity – the responsibility for a safe and efficient payment market, monetary policy and the task of maintaining financial stability. The question also touches on almost philosophical musings as to why the need for central banks arose once upon a time. What was then needed was a public institution that created a standard method of payment that the general public could rely on. Several centuries have passed since then, but the same need probably remains. This is why the Riksbank wants to investigate whether an e-krona could be the solution to provide the general public with continued access to central bank money even when Sweden has stopped using cash.

Liquidity Shortages and (Missing) Infrastructure

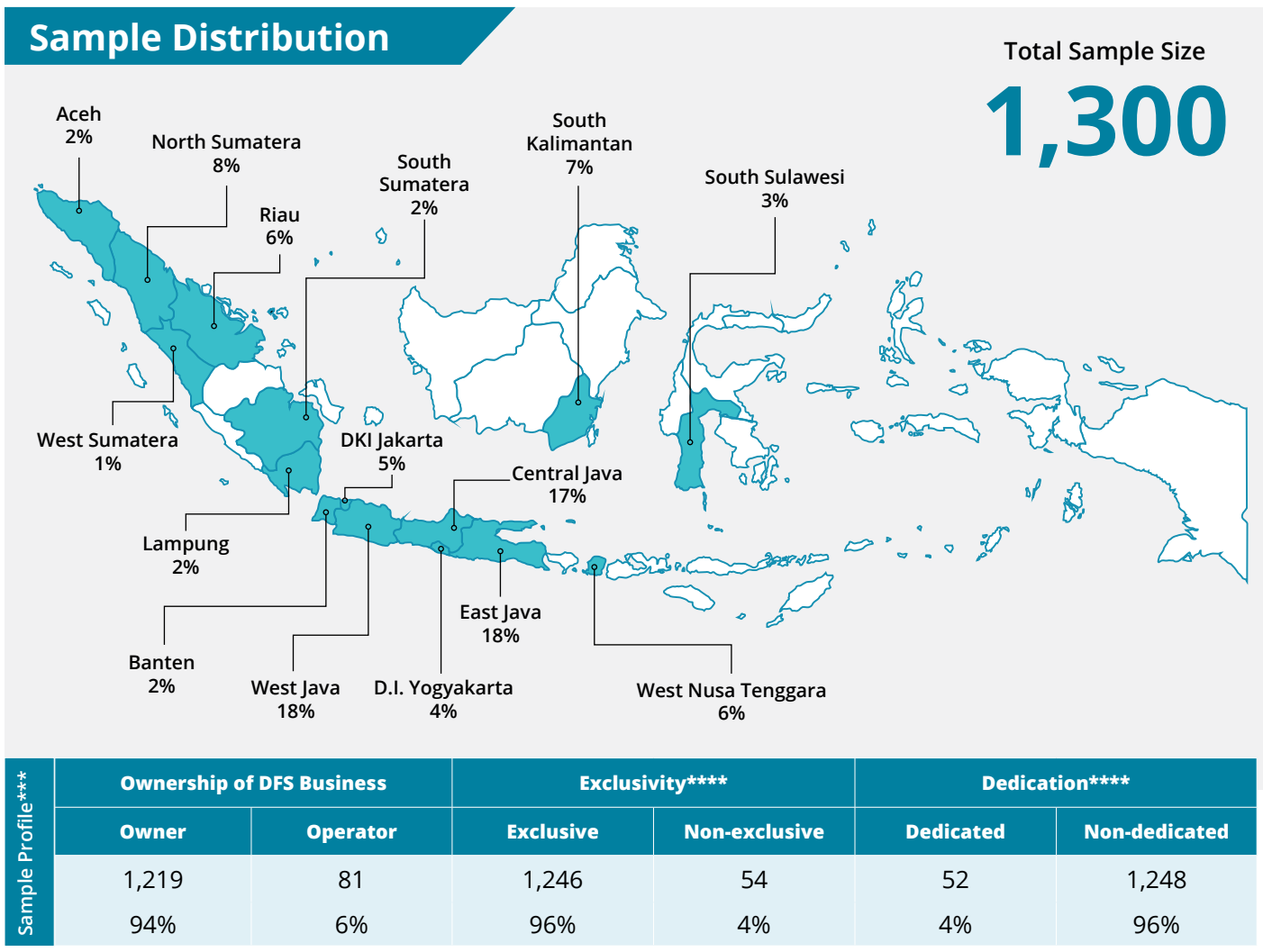
- ❖ A Survey of 250 M-PESA agents as broker dealer in Kenya in late 2008
- ❖ How often do agents run out?

e-Money	Fraction	Cash	Fraction
More than once a day	3.2 %	More than once a day	3.2%
Once a day	6.4%	Once a day	8.4%
Once a week	14%	Once a week	10%
Once a month	5.6%	Once a month	4.8%
Once every 3 months	1.2%	Once every 3 months	1.2%
Once every 6 months	0.4%	Once every 6 months	0.4%
Less often than that	12%	Less often than that	22.4%
Never	57.2%	Never	49.6%

- ❖ Solution: inter-dealer market—it exists but not well documented

Survey Sample*

A total of **15 provinces** were covered nationally as part of the study, as shown in the map below. **Interviews** were conducted in August and September 2017. The provinces covered in the research account for more than **90%**** of the Indonesian agent population.



Sample Geographic Distribution



Laku Pandai & LKD



*The scope of the research was limited to individual DFS agents only. Institutional DFS agents, such as Indomaret and Alfamart, were not included in the research sample. Moreover, only agents who conduct at least one transaction per month (active agents) were interviewed as part of the survey (30% of individual agents encountered were dormant).

**As per the publicly available data on service provider (BRI, BTPN, BNI) website, accessed on 19th June, 2017. For Bank Mandiri, the agent data was shared by the bank with MicroSave for the purpose of this study. BRI (<http://bri.co.id/other?id=37>); BTPN (<https://www.btpn.com/id/tentang-kami/segmen-usaha/btpn-wow-informasi-agen>); BNI (<http://bni.co.id/id-id/locator/agen46locator.aspx>)

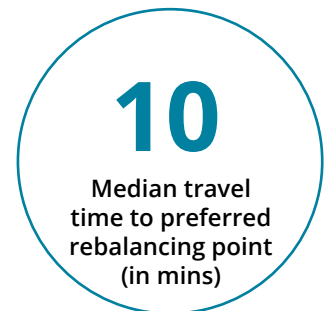
***See Appendix 1 for further detail.

****See Appendix 2 for further detail.

*****Jakarta, Bogor, Depok, Tangerang, Bekasi (Cities under Greater Jakarta Area)

The Majority of Indonesian Agents Travel to the Nearest Bank Branch to Re-Balance

- ▶ Agents who travel to rebalance **mostly (83%) use the nearest bank branch.**
- ▶ For the agents who have liquidity delivered, 52% get the liquidity via regular support staff visits while 41% avail of the on-demand facility provided by their service provider.
- ▶ **The majority of agents (51%) generally require more e-float** while 23% generally need cash. High e-float requirements are associated with higher numbers of money transfer, deposit and bill payment transactions.
- ▶ The **average Indonesian agent does not deny any transaction** due to lack of liquidity.



Liquidity Management Attributes

Agents who travel to rebalance

63%

Agents who have liquidity delivered

41%

Median frequency of rebalancing e-float by the agents (per month)

3

Median frequency of rebalancing cash by agents (per month)

2

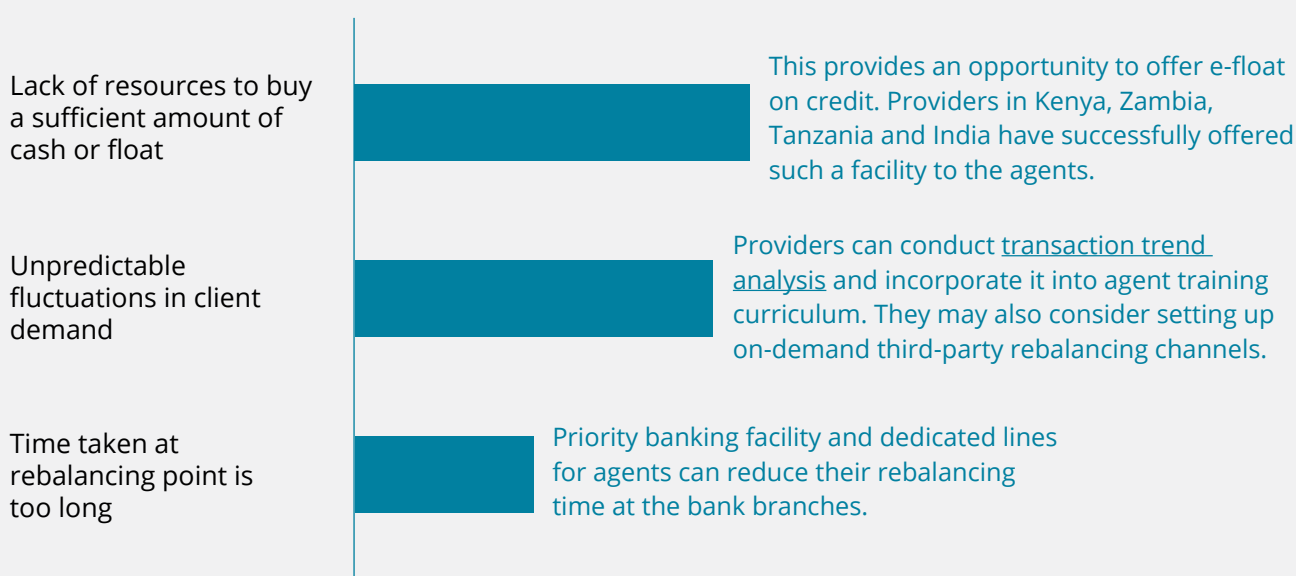
The **majority** of Indonesian agents (63%) have to travel outside their shops to rebalance **unlike in Bangladesh and Pakistan where over 95% have liquidity delivered** to them by a service provider, distributor or third party.

Given the relatively low transaction volumes, **Indonesian agents rebalance less frequently than in Pakistan and Bangladesh**, where a median agent rebalances 15 times a month for e-float and 10 times for cash.

Agent Satisfaction with Liquidity Management Systems

Close to **two-thirds** of agents (63%) stated that they **face barriers in managing liquidity**.

Relative ranking* of barriers agents encounter in managing liquidity



*Agents were asked to select the top three barriers they face from a list of 13 options, including the option to pick 'Other'. The taller bars imply a higher relative ranking, which is a weighted average of the barriers ranked by agents.

Chandrasekhar, Townsend and Xandri (2019)

“Financial Centrality and The Value of Key Players”

- ❖ Our paper is about liquidity and the value of key traders. We model settings in which disruptions to markets take the form of shocks to market participation, referred to for short as blackout periods. Existing literature embraces this notion for assets. For example, U.S. treasuries as safe assets trade with a liquidity premium while other assets bear a illiquidity discount. That is, the market for Treasuries stays active even in rough periods. Existing literature also studies dealers in this context, as providing liquidity to the market, leaning against the wind. We adopt a generalized notion of shocks to market participation which can vary over traders, rather than assets. This includes both exogenous and endogenously determined participation. We study liquidity and the value of key traders in this context as key issues. For us the most valued players are those that provide liquidity when it is most needed, when markets are thin and risk is otherwise high and detrimental.
- ❖ Our paper is closely related to existing literature but makes a new contribution. In Duffie, Garleanu, Pederson there is a single underlying consumption good and two types of assets, a safe liquid asset such as a bank account which can be traded instantaneously and a consol that requires finding a trading partner, in a search environment. Traders buy and sell these assets with themselves and with market makers. The motive for trade has to do with costs of holding the consol, which is stochastic and trader specific. Some traders have high holding costs, interpreted as having a need for cash or having hedging reasons to sell. Again, search frictions make the markets imperfect. Liquidity premia arise in these settings and increase with the costs of finding trading partners.

Chandrasekhar, Townsend and Xandri (2019) (cont.)

- ❖ For us here in this paper, we feature risk averse traders who would like to hedge the risk they face, but who suffer from market participation risk. Further, as the number of market participants is limited and can be small, even iid portfolio returns do not net to zero. Thus both idiosyncratic shocks and market participation shocks create aggregate risk. Traders who provide liquidity to such markets bring their exogenous risky endowment plus their liquid asset holdings to the market and are especially valuable. We study asset pricing in the context, focusing on the value of each trader i in the provision of liquidity, specifically by pricing an Debreu asset that pays off only when trader i is in the market.
- ❖ Longstaff studies value of liquidity and the distinction between on-the-run vs off-the-run treasuries. He is also featuring liquidity that can vary across assets. He incorporates market runs and features the idea, with a leading quote from Alan Greenspan, that individuals who were moving (in the crisis) from, illiquid U.S. Treasuries to the liquid on-the-run liquid issues, are basically saying, “I want out. I don’t want to know anything about whether a particular investment is risky or not. I just want to disengage.” And the reason you go into these liquid instruments is that that is the vehicle which enables one to disengage as quickly as possible. (Alan Greenspan, October 7, 1998). Duffie characterizes Longstaff as studying empirically the impact of blackout periods, which again we adopt in our model as stochastic and varying across traders.

Chandrasekhar, Townsend and Xandri (2019) (cont.)

- ❖ P A Weil's studies the role of market makers in providing liquidity when there is large and temporary pressure as well as order execution delays. He refers to market makers as leaning against the wind. They buy when the pressure is large, accumulate inventories, and sell when the pressure alleviates. The paper studies optimal dynamic liquidity provision in a theoretical market Weil solves, as we do, for Pareto optimal allocations and shows that competitive market makers offer the socially optimal amount of liquidity, provided they have access to sufficient capital. If raising capital is costly, this suggests a policy role for a lenient central-bank lending during financial disruptions.
- ❖ For us here in our paper, key traders look like market makers in the sense that they provide liquidity to a subset of traders. However, unlike Weil, we focus on quantifying the value of such market maker and potential heterogeneity among them. Like Weil, we also move beyond marginal movements in liquidity and study optimal central bank provision liquidity, which should identify key traders as those to whom liquidity should be targeted, as they have maximally valued market participation in the economic sense of our model.

Chandrasekhar, Townsend and Xandri (2019) (cont.)

- ❖ Lagos and Zhang feature the role of Central Banks in the provision of liquidity. Tight money increases the opportunity cost of holding bank reserves and money balances that are used to make payments. They term this a turnover-liquidity (transmission) mechanism. The model features Lagos and Wright 2005 REF model of limited market participation, with a decentralized OTC markets, coupled with subsequent trade in a centralized Walrasian market. Assets are trees with dividends which can become unproductive with positive probability and equities are traded on these trees. There is a second financial instrument, money, that is intrinsically useless. A monetary authority injects or withdraws money via lump-sum transfers or taxes to investors in the second subperiod, in the Walrasian market. We adopt an extreme version of this, liquidity can only be injected via traders carrying it into markets and not when agents are in autarky.

Risk Sharing Program

- *Classical Risk Sharing problem*: A social planner (with weights λ) chooses allocation $c = (c_i(y))_{i \in I}$ to solve

$$V(\lambda) := \max_{c=(c_i(y))_{i \in I}} \mathbb{E}_y \left\{ \sum_{i=1}^N \lambda_i u[c_i(y)] \right\}$$

subject to

$$\sum_{i \in I} c_i(y) \leq \sum_{i \in I} y_i \text{ for all } y \in \mathcal{Y}$$

Stochastic Financial Networks

- Market participation shock: only a random subset of agents can trade.
- Formally, let $\zeta \in \mathcal{M} = \{0,1\}^n$ be the description of which agents can trade, so
 - If $\zeta_i = 0 \implies c_i = y_i$
 - If $\zeta_i = 1 \implies c_i$ may be $\neq y_i$
- Agents that can trade can pool resources:

$$\sum_{i \in I} \zeta_i c_i \leq \sum \zeta_i y_i \text{ for all } y \in \mathcal{Y}, \zeta \in \mathcal{M}$$

- The process ζ is what we refer to as a Stochastic Financial Network

Financial Centrality

- Let $V_{i,\varepsilon}(\lambda)$ be the value of program 1 under a liquidity injection to agent i

Definition (Financial Centrality of i)

$$FC_i := \frac{\partial V_{i,\varepsilon}(\lambda)}{\partial \varepsilon} \Big|_{\varepsilon=0}$$

i.e. the marginal social benefit of giving a small unit of extra income to agent i every time i is in the market, and trades with it as per contracts and markets.

- Price theoretic version of “derivative w.r.t agent i ”

Financial Centrality as guide to Policy

- **Policy experiment:** give income injections (i.e. liquidity) $\varepsilon_i \geq 0$ to a subset $J \subseteq I$
- **Limited resources:** $\sum_{i \in J} t_i \leq T$
- **Objective:** choose $\varepsilon^* = (\varepsilon_i^*)_{i \in J}$ to maximize $V_\varepsilon(\lambda)$ s.t $\sum_i \varepsilon_i \leq T$ and $\varepsilon_i \geq 0$

Proposition

For any $J \subseteq I$, $\exists \hat{T}$: if $T \leq \hat{T}$ then $\varepsilon_i^* = \hat{T}$ for $i = \underset{i \in J}{\operatorname{argmax}} FC_i$ and $\varepsilon_j^* = 0$ for $j \neq i$

Large Transfers

Responsiveness of Stochastic Financial Networks

- A marginal liquidity injection has 2 possible effects:
- ① Risk Sharing effect: an additional dollar given to agent i propagates through the risk sharing contract
- ② Participation Effect: injection works as a subsidy for participation.
- Risk sharing effect is the marginal effect on the reduction of consumption volatility
- The participation effect may appear in models of endogenous market entry. Typically, market participation decisions are strategic complements.

Responsiveness of Stochastic Financial Networks

- Endogenous entry:

$$\Pr(s) = \underbrace{\Pr(y)}_{\text{exogenous}} \times \underbrace{\Pr(\zeta | y)}_{\text{endogenous}}$$

- We need to model the entry decisions through $\Pr(\zeta | y)$
- Let

$$\mathbf{S}_i(\zeta | y) := \left. \frac{\partial \ln(\Pr(\zeta | y))}{\partial \varepsilon_i} \right|_{\varepsilon_i=0}$$

be the score of the likelihood of market ζ with respect to a marginal injection to agent i

Financial Centrality for Inert Environments

- For most of this talk, we will assume the environment is inert.
- This will help with the characterization, and to separate both risk sharing and participation effects.
- Write the Lagrangian of (1) as

$$\mathcal{L} = \mathbb{E}_s \left\{ \sum_i \lambda_i u_i [c_i(s)] + q(s) \left[\sum_i \zeta_i (y_i - c_i) \right] \right\}$$

where $q(s) = q(\zeta, y)$ is the Lagrange multiplier of constraint 2.

Proposition

If $\Pr(\zeta, y)$ is inert to marginal liquidity injections to agent i , then

$$FC_i = \mathbb{E}_s [\zeta_i q(s)]$$

Financial Centrality for Responsive Environments

Proposition

If $\Pr(\zeta, y)$ is responsive to marginal liquidity injections to agent i , then

$$FC_i = \underbrace{\mathbb{E}_s[\zeta_i q(s)]}_{\text{risk sharing eff.}} + \underbrace{\mathbb{E}_s \left\{ \sum_{j \in I} \lambda_j u_j(c_j(s)) \times \mathbf{S}_i(\zeta | y) \right\}}_{\text{participation eff.}}$$

- The first term measures the value of relaxing the resource constraints 2 where agent i is trading, taking the market participation process as given
- The second term measures the change in the value from marginally changing the market participation process.